

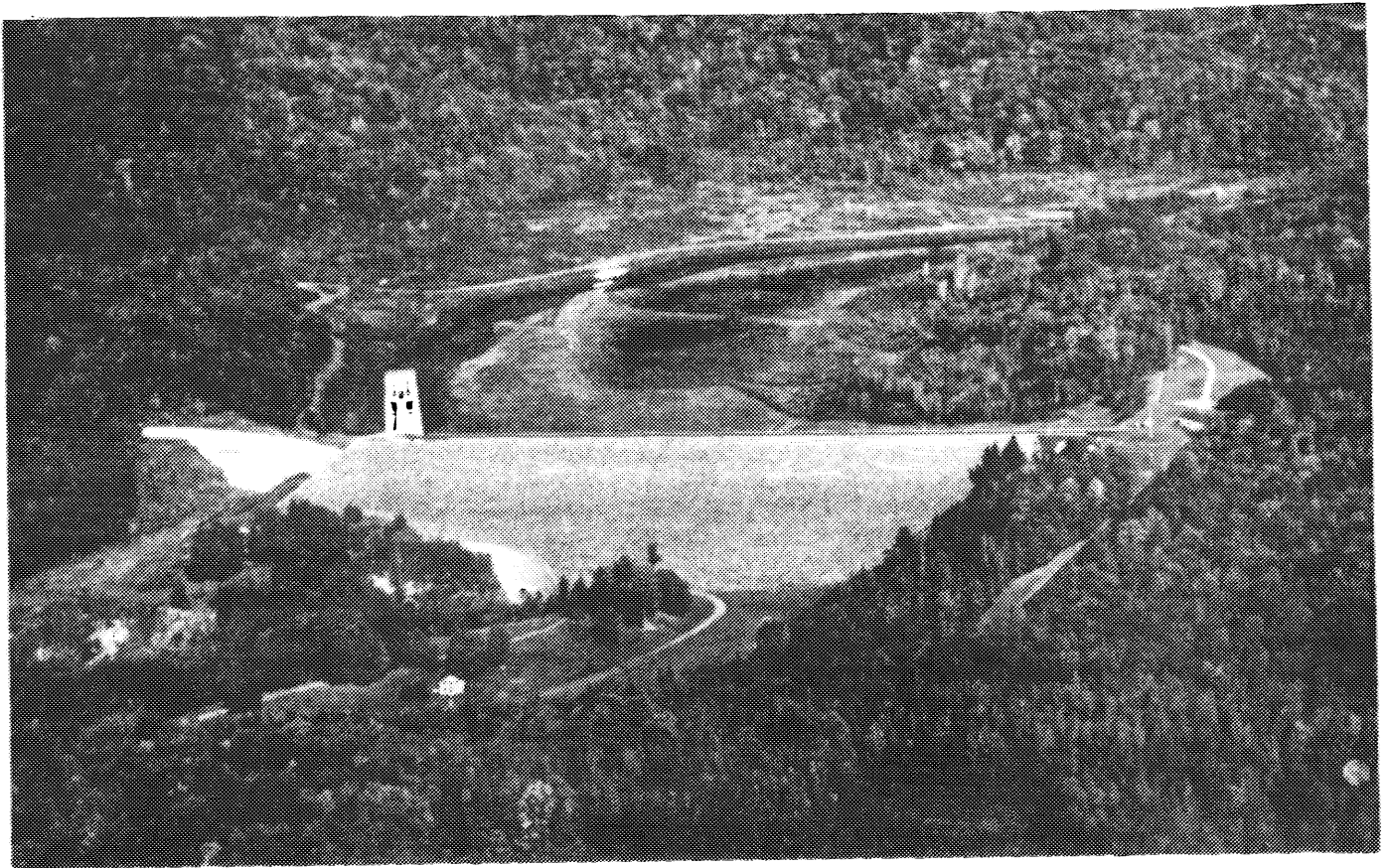
CONNECTICUT RIVER BASIN

KNIGHTVILLE DAM

MODIFICATION

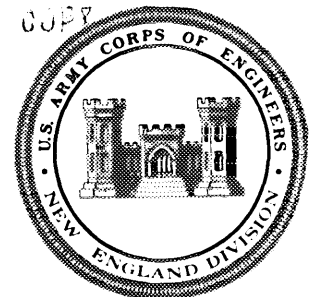
WESTFIELD RIVER
MASSACHUSETTS

FEASIBILITY REPORT FOR WATER RESOURCES DEVELOPMENT
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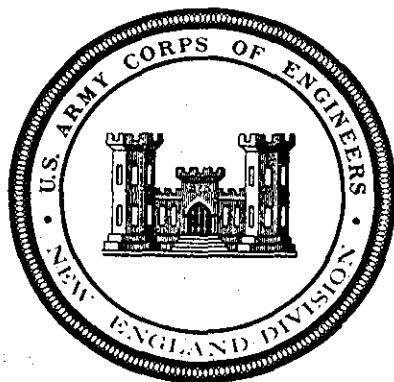
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JUNE 1978



KNIGHTVILLE DAM MODIFICATION

FEASIBILITY REPORT FOR WATER RESOURCES DEVELOPMENT



JUNE 1978

Syllabus

This report is being submitted as a result of a study which investigated the feasibility and desirability of modifying the existing Corps of Engineers' Knightville Dam and Reservoir project to provide storage for additional flood control, a recreational pool and low-flow augmentation to enhance the downstream fishery resources. The existing dam and appurtenant structures were reviewed to determine their stability under present design criteria, and the hydrologic and hydraulic inputs were recomputed based on present criteria and conditions.

The Knightville Dam and Reservoir project is located in the Towns of Huntington and Chesterfield, Massachusetts on the main branch of the Westfield River. Construction of the dam and other structures was initiated in 1939 and completed in 1941. Investigations have determined that modifying the Knightville project to provide single-purpose additional flood control storage would not be economically justified when viewed as "last added" in a system for flood control in the Westfield River Basin. This is based on recent support for the proposed local protection project for the City of Westfield that would protect the main damage center in the basin. Although this report reflects single-purpose flood control can be economically justified on a first added basis, it is not considered a wise use of public funds as downstream flood reductions are minimal when compared to the potential major flood losses in the City of Westfield. Studies of multiple purpose uses of storage for recreation and low-flow augmentation were considered but found not feasible because of environmental reasons as well as a lack of support from other Federal and non-Federal interests. Should attitudes change as relates to multiple-uses at Knightville and local support for the ongoing planning studies for the Westfield Local Protection Project, these matters could be re-examined at that time.

Investigations also determined that modifications to the existing spillway at Knightville are necessary to meet updated design criteria. In order to conform to current design criteria, the spillway would be stabilized by installing a system of post-tensioned rock anchors along the existing concrete structure. These modifications have an

estimated first cost of \$230,000. Inasmuch as the Corps is responsible for assuring the structural adequacy of its civil works structures, the test for economic justification is not considered necessary. Environmental and social effects associated with this modification are considered to be insignificant and in fact beneficial as relates to public safety since the proposed action involves the strengthening of an existing structure, thereby securing its stability and enhancing its intended purpose.

The Division Engineer recommends that funds be made available to strengthen the existing spillway as reported herein and that such action be accomplished under the Corps' normal Operation and Maintenance program.

KNIGHTVILLE MODIFICATION
WESTFIELD RIVER, MASSACHUSETTS

FEASIBILITY REPORT

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KNIGHTVILLE DAM MODIFICATION WESTFIELD RIVER, MASSACHUSETTS FEASIBILITY REPORT

THE STUDY AND REPORT

PURPOSE AND AUTHORITY

Knightville Dam and Reservoir was authorized as one element in a system of flood control reservoirs by the 1938 Flood Control Act, (Public Law 75-761). Although the 1941 Flood Control Act (Public Law 77-228) modified the 1938 Flood Control Act by extending the authorization to cover project uses other than flood control, changes in the contemplated resource uses of Knightville went beyond the scope of the 1941 authorization under which the project was constructed. This survey scope study was, therefore, conducted to ascertain the advisability of modifying the existing project authorization. It was undertaken under authority of United States Senate Resolution, Committee on Public Works, adopted 11 May 1962, as follows:

"That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 12, 1902, be, and is hereby, requested to review the reports on the Connecticut River, Massachusetts, New Hampshire, Vermont, and Connecticut, published as House Document Numbered 455, Seventy-fifth Congress, second session, and other reports, with a view to determining the advisability of modifying the existing project at the

present time, with particular reference to developing a comprehensive plan of improvement for the basin in the interest of flood control, navigation, hydroelectric power development, water supply, and other purposes, coordinated with related land resources."

EXISTING KNIGHTVILLE PROJECT

Knightville Dam is located on the Westfield River about 4 miles north of the Town of Huntington. Construction of the dam and other structures was initiated in 1939 and completed in 1941 at a cost of \$3,220,400, including the cost of the recreational facilities.

The dam is of the hydraulic earthfill type with a dumped rock shell. It has a top length of 1,200 feet and a maximum height above the streambed of 160 feet. A curved concrete spillway, 400 feet long, is located on rock in a saddle at the west end of the dam. The crest of the spillway is 20 feet below the top of the dam to protect the dam from overtopping during a maximum probable flood. Gated outlet works, founded on bedrock, are located under and at the right end of the dam embankment. The gates, three in number, are normally kept open and the reservoir empty. During times of flood, the gates are closed to store floodwaters in the reservoir. The reservoir has a flood control storage capacity of 49,000 acre-feet, equivalent to 5.7 inches of runoff from the drainage area of 162 square miles. If it should fill to spillway crest elevation, the reservoir would have a surface area of 960 acres and extend about 5 miles upstream in Huntington and Chesterfield. A general plan of Knightville Dam is included as plate 2.

SCOPE OF THE STUDY

This report presents the results of studies concerning modification of the project purposes of Knightville Dam to provide a permanent recreational pool, low-flow augmentation to enhance the fishery and additional flood control storage. The existing dam and structures were also analyzed to determine their stability under present day design criteria with the hydrologic and hydraulic analysis recomputed on the basis of present conditions. Emphasis was given to those cities and towns that would be directly affected by modifying Knightville Dam, namely those communities in which the project is located as well as those along the Westfield River downstream of the project. The Westfield River Basin is shown on plate 1. Several alternative plans were investigated to solve the area's water resources problems. The selection of the most feasible plan was made after considering all factors, including those expressed by concerned agencies and local interests.

STUDY PARTICIPANTS AND COORDINATION

The advisability of modifying the project purposes at Knightville Dam required close coordination between the Corps of Engineers, Federal, State and local officials, and interested associations and individuals. This coordination included workshop meetings to determine the needs and desires of State, local and other interests, and a public meeting held in Huntington, Massachusetts on 15 June 1976.

Pertinent correspondence exchanged among participants during the study is contained in Appendix 2.

THE REPORT

This report is presented in two parts, namely the main report and three appendices. The main report provides the results of the feasibility studies and provides a broad view of the overall study together with recommendations. Appendix 1 presents the results of a hydrologic review of spillway and storage capacities at Knightville Dam. Appendix 2 contains pertinent correspondence while Appendix 3 contains a report on the stability analysis of structures at the dam.

PRIOR STUDIES AND REPORTS

The report dated 20 March 1937 and printed as House Document 455, 75th Congress, 2nd Session, reviewed previous reports on flood control for the Connecticut River Basin. A revised comprehensive plan for flood control followed which recommended construction of 20 reservoirs and dikes at seven localities, including Knightville Reservoir on the Westfield River. This plan was authorized by Public Law 761, 75th Congress, approved 28 June 1938.

An interim report dated 29 January 1940 and printed as House Document 653, 76th Congress, 3rd Session, considered revisions of authorized local protection works at seven localities, including West Springfield along the Westfield and Connecticut Rivers. The report recommended that the authorized plan be modified to provide for construction of the local works in accordance with revised plans. The plan was

authorized by Public Law 228, 77th Congress, approved 18 August 1941.

Flood control and allied water uses in the Westfield River watershed were discussed in part 2, Chapter XXI, of "The Resources of the New England-New York Region" NENYIAC Report. This report was a comprehensive survey of the land and water and related resources of the New England-New York region prepared by the New England-New York Inter-agency Committee. The report was submitted to the President of the United States by the Secretary of the Army on 27 April 1956. The flood control plan set forth in this report included two flood control reservoirs in the Westfield River watershed, Knightville (constructed) and Littleville (recommended).

An interim report dated 30 April 1956 and printed as Senate Document 17, 85th Congress, 1st Session, reviewed the need for additional flood control reservoirs in the Westfield River watershed and recommended that the authorized plan for flood control in the Connecticut River Basin be revised to include Littleville Dam and Reservoir on the Middle Branch of the Westfield River. This project was authorized by the Flood Control Act of 1958, approved 3 July 1958.

A Flood Plain Information Report for the City of Westfield was prepared by the New England Division, Corps of Engineers and published in June 1969. This report, prepared for the City of Westfield, delineates the flood plains of the Westfield and Little Rivers.

A 7-year Federal-State Level-B study effort resulted in a report, "Comprehensive Water and Related Land Resources," dated June 1970. The Coordinating Committee, which guided this study, recommended a 1980 Connecticut River Basin Plan to meet the immediate water related needs of the basin. One of several elements of that plan was the major structural modification of the existing Knightville project.

The Water Resources Council in reviewing the Connecticut River Comprehensive Study determined that further flood control studies were needed in the Connecticut River watershed. Accordingly, the Council asked the New England River Basins Commission to chair a Federal-State supplemental study of Connecticut River Basin. The resulting report, "The Rivers Reach," dated December 1976, presented a unified program for flood plain management in the Connecticut River Basin. This program emphasizes the use of nonstructural measures to reduce vulnerability to flooding and, within this long-term regional strategy, the use of structural measures to modify flooding in specific local situations.

The Northeastern United States Water Supply Study (NEWS), started in 1966 and completed during 1977, is an aftermath of the unprecedented drought that started in 1960 over the northeastern seaboard of the United States. In October 1965, Congress authorized the Secretary of the Army to cooperate with Federal, State and local agencies in preparing plans to meet the long-range water needs of the northeastern States. The NEWS study area includes all of the river basins that drain into Chesapeake Bay, the Atlantic Ocean north of Chesapeake Bay, Lake Ontario and the St. Lawrence River. It is anticipated that future plans to meet the water needs of this area may include major catchment reservoirs, large conduits to transfer water from one basin to another, and major purification facilities to be constructed under Federal auspices with appropriate non-Federal financial participation.

STUDIES IN PROGRESS

A study of local flood protection for the densely populated flood plain of the City of Westfield is in progress. Alternatives under consideration provide for varying lengths of earth dikes, concrete floodwalls, channel relocations and appurtenant

structures along the Westfield and Little Rivers and Powdermill Brook. The study is being conducted in accordance with the long-range planning concepts of the Connecticut River Basin plan and is scheduled for completion in fiscal year 1978.

In response to recommendations included in "The Rivers Reach", the Corps has initiated flood plain management studies for six communities in the Connecticut River Basin. These communities include East Hartford, Glastonbury, Rocky Hill and Wethersfield, Connecticut; Northampton, Massachusetts and Keene, New Hampshire. The studies will examine all techniques of flood plain management within the 100-year flood limit. These techniques include flood proofing, raising or re-locating structures, instituting flood plain zoning and certain building code requirements, purchasing flood-prone land or development rights on this land, developing a flood warning and evacuation program and applying the National Flood Insurance Program. The studies will also examine the institutional arrangements that will be necessary to implement a successful program and establish cost-sharing arrangements. The studies are scheduled to be completed by 1981.

RESOURCES AND ECONOMY OF THE STUDY AREA

Knightville Dam and Reservoir is located in the Towns of Huntington and Chesterfield, Massachusetts on the main branch of the Westfield River. The Westfield River Basin, the fifth largest watershed in the Connecticut River Basin, covers a large portion of the eastern slopes of the Berkshire Hills in Western Massachusetts. The watershed has a total drainage area of 517 square miles, an approximate length in a north-south direction of 48 miles, and an average width of about 11 miles (see plate 1). Principal tributaries of the Westfield River include the West and Middle Branches of the Westfield River and the Little River. Drainage areas of the Westfield River and its principal tributaries are listed in the following tabulation:

River	Location	Miles above Mouth of West- field River	Sq. Miles Drainage Area
West field River	Mouth	0.0	517
	Westfield at West- field Gage	8.4	497
	Confluence with Little River	11.3	361
	Above Upper City Limit	17.3	347
	At Knightville Dam	28.3	162
West Branch	At mouth	24.7	93.7
Middle Branch	At mouth	26.0	52.6
Little River	At mouth	11.3	84

The study area encompasses those communities that would be directly affected by modifying the Knightville Project. This includes the City of Westfield and the Towns of Chesterfield, Huntington, Montgomery, Russell, Agawam and West Springfield, Chesterfield and Huntington have project lands within their boundaries. The others, communities situated along the Westfield River downstream of the project, are affected by flood control operations at the dam.

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

The western fringe of the study area is mountainous with steep slopes reaching to elevations of 1,300 feet. In this rugged upland region, streams flow swiftly through narrow and steep-sided valleys toward the broad valleys in the eastern portion of the study area. Within these broad and relatively shallow valleys, the gradient of the Westfield River flattens and sizable flood plains abut the river.

A large portion of the study area is in the rugged upland region which is composed of geologic formations strikingly different from those underlying the extensive Connecticut River lowland. These formations are made up of ancient crystalline rock of igneous and metamorphic origin. The much younger geologic formations are composed chiefly of slightly inclined sedimentary strata. These softer formations are in turn overlaid by thick glacial deposits, making possible a few profitable sand and gravel pit operations. A noted geological feature in the basin is the Chesterfield Gorge, a chasm located on lands owned and managed by the Trustees of Reservations about 6.5 miles upstream of Knightville Dam.

The climate of the Westfield River Basin varies according to the topography, with the lower elevations in the eastern portion of the study area experiencing a milder climate than the higher elevations to the west. The mean annual temperature varies from 50° F in the lower valleys to 44° F in the mountainous regions. Extremes of 102° F and 30° F have been recorded in the basin. Precipitation averages about 46 inches annually and is fairly uniform throughout the year. The mountainous region receives slightly more precipitation than the valley, especially in the winter. Mean annual runoff for the Westfield River is 26.12 inches.

The study area is rich in natural resources. The Westfield River and its tributaries are used for recreation, fish and wildlife, power, and municipal and industrial water supply. Terraces and ridges are covered by mature woodlands of the northern hardwood's zone, characterized by American beech, yellow birch and sugar maple. More open areas and former farmlands nurture

short-lived pioneer species such as aspen and grey and paper birch.

In unpopulated areas, such as the one surrounding Knightville Dam, there are white-tailed deer, a few black bear, red and grey foxes, raccoon, otter, beaver and many smaller animals. Small populations of wood ducks and hooded merganzers inhabit the area and black ducks, blue-winged teals, green-winged teals and American merganzers use the Westfield River as a feeding and resting area during migration. Fish are plentiful here. These include warm water species such as perch, bass and pickerel in the lower portion of the Westfield River and cold water species such as brown and rainbow trout in the upper portion and in tributary streams.

Since its completion, the Knightville project has provided an area for hunting and fishing, and, in recent years, a camping area has been established. One of the State's most heavily stocked and hunted pheasant areas is located in the reservoir. A State trout stocking program also insures good fishing in the vicinity of the dam. In addition, in conjunction with the Westfield Chamber of Commerce, stored floodwater has been released during the spring months to make white-water canoeing possible.

HUMAN RESOURCES

The 1970 census placed the population of the study area at 85,726. This reflects an 84 percent increase over the 1930 population of 46,614 for a compound growth rate of 1.5 percent per year. A 1970 Lower Pioneer Valley Planning Commission report projects a total population of 113,600 by 1990, an increase of 33 percent. This projection of a compound growth rate of 1.4 percent per year is comparable to the historical steady growth of the area and appears to be reasonable.

The major centers of population, or urban areas, include Westfield, West Springfield and Agawam. They account for 85 percent of the people in the study area. The population density of the urban

areas averages 937 persons per square mile while the remaining rural towns average 47 persons per square mile. Population density has increased in both urban and rural areas in the past, and it is expected that this trend will continue because of the availability of buildable acres and the recent increase in construction of multifamily dwellings in urban areas.

While information for all communities was not available, the following tabulation of county statistics for 1970 provides data which is representative of the study areas. The Towns of Chesterfield and Huntington are situated in Hampshire County and the remaining communities are situated in Hampden County.

ITEM	Hampden County	Hampshire County
Population	459,070	123,981
Population Density (persons/sq. mile)	737	234
Median Age	29.1	24.8
Median Family Income	\$8,431	\$5,197
Per Capita Income	\$3,240	\$3,008
Education Attainment (School years completed)	12.1	12.2

DEVELOPMENT AND ECONOMY

Within the study area, West Springfield, Westfield and Agawam are the only communities having major commercial or industrial districts. They also have a significant amount of residential land and parcels of agricultural, recreational and open land. In the remainder of the study area, which includes the Towns of Huntington, Chester-

field, Montgomery and Russell, developed land is used primarily for recreation, agriculture and housing. However, much of the land in these sparsely populated towns is undeveloped.

Land use for the study area is shown in the following tabulation:

Land Use Category	Acres	Percent
Residential	8,185	7.3
Commercial and Institutional	1,614	1.4
Industrial	1,061	1.0
Transportation	4,520	4.0
Recreational	18,244	16.3
Agricultural	14,067	12.5
Vacant Land	<u>64,569</u>	<u>57.5</u>
	112,260	100.0

In both Hampshire and Hampden Counties, the manufacturing industry employed the largest percentage of people in 1971, with the service industry ranking second in Hampshire County and wholesale and retail trade ranking second in Hampden County. Manufacturing activity is concentrated in West Springfield, Westfield and Agawam, where paper products, machinery, electrical equipment, packaging materials, heating equipment, sporting goods and chemicals are major products. In smaller, more remote towns in the study area, the trade and service industries are more important since they focus on summer and fall recreation and tourism.

Excellent transportation routes, including interstate and state

highways, railroads and two airports, tie the area to other population centers such as Boston and Springfield. The availability of this system makes the area suitable for industrial and other economic development.

The general location and availability of a skilled labor force offers a potential for industrial growth in the urban areas. Continued growth and dispersion would increase the demand for housing as well as stimulate growth in the consumer-oriented businesses.

Rural communities in the study area should continue to experience years of slow population growth and land development. The countryside will likely maintain its character of small central communities with surrounding agricultural, recreational and undeveloped lands. Recreation should continue to rank among the most important future-growth industries in this area.

PROBLEMS AND NEEDS

The water resource problems and needs include flooding along the Westfield River downstream of the Knightville project, recreation, consideration of the use of low-flow augmentation to enhance the fishery and changes in design criteria since the project was completed.

STATUS OF EXISTING PLANS AND IMPROVEMENTS

Existing flood control improvements affecting the Westfield River

include the West Springfield and Riverdale Local Protection projects, Knightville Dam, and Littleville Lake, a multipurpose flood control and water supply reservoir. Three Soil Conservation Service flood retarding structures are also located within the basin. A dike constructed by the Commonwealth of Massachusetts is located along the right bank of the Westfield River in the vicinity of the Elm Street Bridge in Westfield. In addition, storage is provided at several water supply reservoirs which provide some incidental flood control.

The improvements noted are discussed in more detail in the following paragraphs.

(a) Local Protection

The West Springfield flood protective works are located along 2 miles of the west bank of the Connecticut River and 3 miles of the north bank of the Westfield River. The project included the construction of earth dikes, floodwalls, three stoplog structures and five pumping stations. Construction was started in 1936 and the latest improvement was completed in 1953. About 1,100 acres of highly developed industrial, commercial, public and residential property is protected. The project is operated and maintained by the Town of West Springfield.

At Westfield, the dike on the right bank of the Westfield River upstream of the Elm Street Bridge was constructed by the city prior to 1869. This dike has been overtopped or washed out several times. After the 1938 flood, it was rebuilt and extended downstream by the Commonwealth of Massachusetts. In 1955 this dike failed again by overtopping. Although the dike has since been repaired, it gives only limited protection to a highly developed section of Westfield.

A study of local flood protection for the City of Westfield is in progress. Alternatives provide for varying lengths of earth dikes, concrete floodwalls, channel relocations and construction of appurtenant structures along the Westfield and Little Rivers and Powdermill Brook. Westfield is located in the lower Westfield River watershed. Although additional storage at the Knightville project would reduce the level of flooding in Westfield, the city would still be subject to flooding from the uncontrolled drainage

area below the Knightville and Littleville project.

(b) Dams & Reservoirs

Littleville Dam is located on the Middle Branch of the Westfield River, one mile upstream of its confluence with the main river. Completed by the Corps in 1965, the project provides a multipurpose flood control and water supply reservoir with a total storage capacity of 32,400 acre-feet, of which 23,000 acre-feet (equivalent to 8.2 inches of runoff from the contributing drainage of 52.3 square miles) is reserved for flood control. The water supply storage, which will yield an average of 17.5 million gallons per day, is for future use by the City of Springfield as a participant under the provisions of the Water Supply Act of 1958. As part of the comprehensive plan for flood protection in the Connecticut River Basin, this project reduces flooding at damage centers on the Westfield and Connecticut Rivers.

(c) Soil Conservation Service

The Soil Conservation Service has completed three flood retarding structures in the Westfield Basin. These are the Black Brook, Powdermill Brook and Arm Brook projects. All of these structures are located on small tributaries of the Westfield River and reduce flooding in areas immediately downstream. Inasmuch as they control a total of only 10.3 square miles or 2 percent of the Westfield River watershed, their effect on reducing flood stages along the Westfield River is relatively minor.

(d) Other

A Flood Plain Information Report for the Westfield and Little Rivers was completed by the New England Division for the City of Westfield in June 1969. Information developed for this report is being used for other Flood Insurance Studies currently underway by the Department of Housing and Urban Development for the City of Westfield and the Town of Agawam.

The Flood Disaster Protection Act of 1973 requires that communities adopt effective zoning and building code regulations in order to qualify for the Federal Flood Insurance Program. Most of the communities along the Westfield River are eligible for emergency

flood insurance and are waiting for Flood Insurance Studies to be accomplished. It is anticipated that these communities will adopt regulations necessary for participation in the National Flood Insurance Program once these studies are completed, but the time frame for qualification is unknown.

A Flood Insurance Study was recently completed for the Town of West Springfield by the Corps of Engineers.

FLOOD PROBLEMS

Damaging floods have occurred along the Westfield River since the founding of the first settlements in the basin. Reliable records of flood stages have been maintained since 1909. Major floods which have occurred in the basin since 1927 are listed as follows:

November	1927
March	1936
September	1938
December	1948
August	1955
October	1955

These floods resulted in the construction of Knightville Dam, completed in 1941, and Littleville Lake, completed in 1965. (See plate 1). Since completion of the Knightville project, there have been about 60 significant reservoir operations. The most notable of these took place in December 1948, when the entire storage capacity of the reservoir was utilized and a small amount of spillway discharge occurred. In August 1955, the reservoir was more than half filled and in October 1955, nearly all of its storage was utilized. Although reservoir operations at the Knightville and

Littleville projects have resulted in a significant reduction in downstream flood damages, areas in the lower Westfield River Valley remain susceptible to flooding from the uncontrolled watershed below these projects.

The areas currently susceptible to flooding in the Westfield River Basin are located on the valley floor in the lower portion of the basin. This area includes the broad flood plain the the City of Westfield and low-lying areas in the Town of West Springfield. The majority of flood losses would occur within the City of Westfield where the Corps is investigating the feasibility of constructing a local protection project. The flood-prone area in Westfield is characterized by extensive development in the central business district and along the main transportation routes. The remainder of the developed flood plain is predominantly residential or agricultural. Within this area there are more than 1,400 residential properties, 350 commercial and industrial establishments, 18 public buildings and 7 farms. These properties have an assessed value in excess of \$40 million.

In West Springfield several residences and three paper mills are susceptible to flooding. Main transportation routes which cross the area are also subject to some inundation. However, most of the town is protected by local protection works constructed by the Corps of Engineers.

Average annual flood damages for that portion of the Westfield River flood plain affected by flood control operations at Knightville Dam and Littleville Lake are estimated to be \$1,485,300. This consists of average annual damage of \$1,376,000 for the City of Westfield and \$44,900 for the Town of West Springfield under current conditions, and \$64,500 due to future economic growth in affluence in these area.

RECREATION NEEDS

Present public use facilities at Knightville Reservoir consist of camping, picnicking, cold water stream fishing, hunting and snow-

mobiling on the 2,430 acre reservation. Stored floodwater has also been released to make white-water canoeing possible. But there is no current permanent pool at the reservoir for recreational pursuits. This natural area also fills a need for passive recreation and provides habitat suitable for fish and wildlife production.

As a component to the Connecticut River Basin Level B Comprehensive Study, the Bureau of Outdoor Recreation prepared a report presenting an outdoor recreation plan for the basin. This report determined that existing and anticipated recreational developments in the portion of the basin would not satisfy the 1980 demand for the four key recreational activities namely camping, picnicking, swimming and boating. Consequently, the redevelopment of several water resource projects, including further development of Knightville Reservoir, was recommended for early action consideration through the Corps of Engineers and the Statewide Comprehensive Outdoor Recreational Programs.

LOW FLOW AUGMENTATION NEEDS

In conjunction with consideration of a recreational pool at Knightville Reservoir a small amount of storage to augment downstream flows and enhance the downstream fishery resource was considered. To prevent interference with the functioning of a recreational pool these releases would be made during the late summer when the recreation pool could be drawn down.

OTHER WATER RESOURCE CONSIDERATIONS

Other water resource needs such as water supply and hydroelectric power generation were investigated in the Level B Comprehensive Connecticut River Basin Report of 1970. It was concluded that additional supplies of water and power are not needed in the study area at the present time but will likely be required in the future.

Hydro-power potentials at Knightville are considered minimal. The creation of a permanent pool and construction of extensive transmission facilities would make such a proposal economically and environmentally less attractive than other alternatives.

REVIEW AND UPDATE OF DESIGN

CRITERIA AT KNIGHTVILLE DAM

Inasmuch as Knightville was designed in the late 1930's and completed in 1941, the existing dam and appurtenant structures were analyzed to determine their stability under present design criteria, and the hydrologic and hydraulic analysis was recomputed based on present criteria and conditions.

STRUCTURAL ANALYSIS

A stability analysis was made of concrete structures at the Knightville Dam. A report of the analysis (dated July 1974) is included in Appendix 3. The analysis considered various loading conditions for the following concrete structures and project features: intake tower, service bridge piers, spillway, spillway retaining walls and concrete toe wall. Studies determined that all structures, except the spillway, meet updated stability requirements.

The spillway is of a gravity wall type with an overflow spillway weir approximately 400 feet long at the crest. The structure is made up of 14 concrete monoliths, each of which must be stable by itself under any loading condition. The three monoliths at the west end of the spillway were provided with steel anchors drilled into rock. To satisfy the overturning stability criteria at maximum flood discharge condition, remedial measures are necessary for the 11 monoliths where no anchorage system was provided.

HYDROLOGIC ANALYSIS

Hydrologic studies of spillway and storage capacities are presented in Appendix 1 and summarized below.

To determine spillway adequacy, the original (1940) spillway design flood analysis was compared to present day criteria. This study demonstrated that the present spillway does not meet current capacity requirements. The developed spillway design flood would not overtop the dam but it would encroach 2.3 feet on the original 5 feet of freeboard. This would result in a remaining freeboard of only 2.7 feet. The storage capacity, which is equivalent to 5.7 inches of runoff, is considered somewhat less than desirable for the control of large hurricane or snowmelt type floods in the mountainous regions of New England. The reservoir has been filled to 100 percent and 96 percent of its capacity during 1948 and 1955, respectively. Neither the spillway capacity nor the storage capacity pose a critical condition. However, additional storage capacity and increased spillway capacity should be considered as an adjunct to other project purposes if these are found feasible.

IMPROVEMENTS DESIRED

During the process of the study, several workshop type meetings were held with Federal, State, Local and private interests to present the status of the investigation, and insure that the plans being studied were acceptable and would satisfy the needs of the basin.

A public meeting was also held in Huntington, Massachusetts on 15 June 1976 to present the various alternatives considered and provide an additional forum for those concerned to express their views on all aspects of the study. Federal, State and Local officials and private citizens were present at the meeting. Those who expressed their views were in general agreement with the need for additional flood control in the lower basin. However, because of the environ-

mental consequences associated with creating a permanent or seasonal pool, providing storage for recreation or low-flow augmentation lacked public support.

FORMULATING A PLAN

A plan was formulated by evaluating all potentially feasible solutions to the water resource problems at Knightville Dam. These alternatives were screened based on technical, economic and intangible criteria to arrive at a plan that best responds to these needs and the desires of Federal, State, Local and private interests.

FORMULATION AND EVALUATION CRITERIA

The following technical, economic, environmental and social criteria were used in the process of formulating and selecting a plan.

Technical Criteria

- a. The Knightville project is regulated primarily to prevent damages in the city of Westfield, the main damage center along the Westfield River.
- b. In determining surcharge depth required at the reservoir, a spillway design flood routing was made starting with a one-half full pool and gates operable.
- c. Current design criteria for dams and appurtenant structures were used to analyze the existing structure and to design modification alternatives.

Economic Criteria

- a. Annual tangible benefits must exceed annual project costs.
- b. From an economic standpoint, the favored plan for modification to Knightville Dam is that which maximizes net benefits.
- c. An interest rate of 6-5/8 percent was used to discount future and redevelopment benefits. The annual cost of each alternative was developed by amortizing the total cost over a 100 year project life at an interest rate of 6-5/8 percent.

Environmental and Social Criteria

- a. An interdisciplinary team of biologists, geographers, civil engineers and other personnel was used to insure proper evaluation of the impacts of various alternatives.
- b. Public health, safety and social well-being, including possible loss of life, were carefully considered.
- c. Coordination was maintained with interested agencies, officials and individuals to insure general public acceptance of possible plans.

SOLUTIONS CONSIDERED

Major structural modification of the Knightville project to provide storage for a recreational pool and low-flow augmentation as well as additional flood control storage were considered. Investigations and meetings with Federal, State local officials concerning these proposals determined the following:

Recreational Pool - Recreational development for all pool levels considered was limited by the topography of the area, which is characterized by steeply sloped narrow valleys. Investigations of both a permanent and summer recreational pool determined that a pool with a surface elevation of 528 feet m. s. l. and surface area of

220 acres would maximize recreational use at the project. At elevation 528 m. s. l. the pool would inundate 2.5 miles of free flowing cold water stream fishery and result in the creation of a warm water fishery of marginal quality. Bottom land, which is presently stocked with pheasants and managed for public hunting, would be inundated. Although a summer pool could be drawn down prior to the fall hunting season, severe damage to existing vegetation could result in the creation of mud flats and subsequent elimination of this activity. Relocating this hunting activity to another area was investigated but no suitable site was located. Fish and wildlife agencies were also opposed to the creation of a permanent or summer recreational pool because of the loss of an existing cold water fishery, as well as the loss of one of the State's most heavily stocked and hunted pheasant areas. Due to high construction costs associated with providing storage for a permanent pool and the fact that the topography would limit recreational development, the State was also reluctant to cost-share in such a proposal. Accordingly, creating a pool for recreation was eliminated as a project purpose at this time.

Low Flow Augmentation - Consideration was given to providing low-flow augmentation in conjunction with recreational development. It was found to have minimal effect on the downstream fishery as the amount of flow augmentation that could be made available was relatively small. Further, these releases would occur during the late summer when the majority of the State stocked fish have been harvested. Flow augmentation for enhancement of the downstream fishery was found to lack economic justification. Benefits accruable to water quality purposes were found to be minimal and lacked support from the Environmental Protective Agency. Providing a pool for flow augmentation alone was discarded as it would produce adverse environmental effects similar to those examined for recreational purposes.

Additional Flood Control Storage - Additional flood control storage at Knightville received major attention in this study. The principal area to be benefited by additional storage would be the city of Westfield, and, as the Corps was considering local protection at Westfield as part of a separate study, the relationship of Knight-

ville Dam to downstream local protection was closely considered. Reviewing Knightville Dam in light of current design criteria, which has changed since the project was designed of the late 1930's, was a further requirement of this study.

Inasmuch as reevaluation of other water resource needs of Knightville proved unwise and lacked support, the planning objectives were directed towards the feasibility of providing additional flood control storage at Knightville Dam and more importantly satisfying updated design criteria. In arriving at a recommended plan, three alternatives were evaluated, namely:

- I. Do Nothing
- II. Modify the Knightville project to conform solely to updated design criteria.
- III. Modify the Knightville Project to conform to updated design criteria and provide additional flood control storage.

Alternative I - Do Nothing

Rely upon existing flood control facilities for flood protection without satisfying current design criteria.

Alternative II - Modify the Knightville Project to Conform Solely to Updated Design Criteria

Stabilize the existing spillway by installing a system of post-tensioned rock anchors. Corps of Engineers' freeboard requirements would be met by operating the gates rather than physically raising the dam and appurtenances. Such an alternative relies on locally sponsored flood plain management measures and structural options such as Westfield Local Protection Project now under study to provide flood protection for that city.

Alternative III - Modify the Knightville Project to Conform to Updated Design Criteria While Providing Additional Flood Control Storage

Operation of the project would remain basically unchanged except that

floodwaters could be stored earlier and held for longer periods with less chance of exhausting storage capacity. This alternative takes advantage of an existing damsite and to provide some small amount of additional flood protection to downstream areas. Changes necessary to meet current design criteria would be included under such a plan.

ALTERNATIVES CONSIDERED FURTHER

During investigations it was found that construction of the proposed Westfield Local Protection Project would provide more positive protection to the majority of remaining flood-prone property downstream of the Knightville project, namely the city of Westfield. If the local protection project were built first, additional storage at Knightville, as defined in Alternative III, could not be economically justified. However, historically the city of Westfield has turned down the local protection project which was initially proposed in 1963. Local cost sharing was given as a reason. Although a letter of intent has since been received from the city of Westfield supporting the local protection project, Alternative III was fully evaluated because the city was hesitant to furnish these assurances.

Amounts of additional flood control storage considered under Alternative III are as follows:

Amounts of Additional Flood Control Storage Considered		Modified Reservoir Capacity	
		(1)	
Acre Feet	Inches of Runoff	Acre Feet	Inches of Runoff
4,320	0.5"	53,320	6.2"
8,640	1.0"	57,640	6.7"
12,960	1.5"	61,960	7.2"
17,280	2.0"	66,280	7.7"

(1) Knightville reservoir has a flood control capacity of 49,000 acre feet, which is equivalent to 5.7" of runoff.

SELECTING A PLAN

Different amounts of additional storage for flood control purposes were evaluated in terms of their effectiveness in controlling downstream flooding and the cost of providing this storage. Alternative methods of raising the dam, stabilizing and raising the spillway, and raising other structures were analyzed to determine the most economical method of modifying these structures.

Estimates of first costs provided for raising the dam, spillway and appurtenant structures and for acquiring the necessary real estate interests. These estimates were based on 1977 price levels and include a contingency allowance of 15 percent. Engineering and design and supervision and administration are estimated lump sum items and amount to about 12 percent. The cost of engineering and design, as compared to projects with a similar cost, was considerably reduced because of the availability of detailed engineering information developed for the original construction. The annual cost for each increment of additional storage was then computed using an interest rate of 6-5/8 percent and a project life of 100 years.

Estimates of average annual benefits expected to result from each increment of additional storage were made based on 1977 price levels. The great majority of area that would be afforded additional protection lies within the extensive flood plains in the City of Westfield. Benefits evaluated include inundation reduction, affluence and area redevelopment. Because a change in the basic nature of the use of the land would not be caused by the project, location and/or intensification benefits were not included.

Annual costs and benefits were compared to determine the point where net tangible benefits would be maximized in order to optimize the amount of additional flood control storage that should be provided at Knightville Dam. This comparison is shown on Table 1. On this

TABLE I
ANNUAL COSTS AND BENEFITS OR
PROVIDING VARIOUS INCREMENTS OF
ADDITIONAL STORAGE

<u>Additional Flood Control Storage</u>		<u>Total Flood Control Storage</u>		Total* First Cost	Annual** Cost	Annual Benefits	B/C Ratio	Excess Benefit Over Cost
Acre-Feet	Inches of Runoff	Acre-Feet	Inches of Runoff					
4,320	0.5"	53,320	6.2"	\$2,215,000	\$147,000	\$145,100	0.99	-\$ 1,900
8,640 ¹	1.0"	57,640	6.7"	\$3,587,000	\$238,000	\$277,500	1.17	\$39,500
12,960	1.5"	61,960	7.2"	\$5,655,000	\$375,200	\$381,300	1.02	\$ 6,100
17,280	2.0"	66,280	7.7"	\$7,300,000	\$484,400	\$486,200	1.00	\$ 1,800

* Based on 1977 price levels.

**Based on an interest rate of 6-5/8 percent and a project life of 100 years.

¹Maximized plan.

The existing Knightville project has a flood control capacity of 49,000 acre-feet, which is equivalent to 5.7 inches of runoff.

basis it was determined that providing 8,640 acre feet of additional flood control storage produced maximum net benefits. Storage beyond this point would not be economically justified on an incremental basis.

Because Knightville Dam has been in existence since 1941, any major social impact which may have resulted from its construction has already occurred and modification of the structure will have only a minor impact on the area.

Environmental impacts of modifying the Knightville project to provide additional storage produce two areas of some minor concern: those related to increased impoundment capacity and those associated with construction. Providing the increments of additional storage as outlined would increase the surface area of the flood control pool at spillway crest from the present 960 acres to between 1,005 (1 1/2") and 1,140 acres (2.0") and would result in the temporary inundation of an additional 45-180 acres of land. The additional impact to existing vegetation is considered to be minor and temporary as the maximum pool elevation would normally be maintained for no more than a few days. Construction would cause temporary increases in noise, dust and traffic congestion. These effects could be minimized by traffic scheduling and adherence to noise and dust control procedures. Some additional structural encroachment on the east end of the dam would disturb existing vegetation, but appropriate landscaping would mitigate any loss of existing shrubs and trees.

After addressing the engineering, economic, environmental and social aspects of each increment of additional storage, providing 8,640 acre-feet of additional flood control storage, while modifying the project to conform to updated design criteria, was found to be the best plan for reducing future flood losses along the Westfield River if the Westfield Local Protection Project is not constructed. The estimated first costs and annual charges of providing this additional storage are summarized in the following tabulation:

SUMMARY OF FIRST COSTS

Dam Embankment	\$1,950,000
Access Road	25,000
Utility Building	25,000
Control Tower and Bridge	127,000
Spillway Retaining Wall	360,000
Spillway	680,000
Engineering and Design	185,000
Supervision and Administration	185,000
Real Estate	50,000
	<hr/>
TOTAL ESTIMATED FIRST COST	\$3,587,000

SUMMARY OF ANNUAL COSTS

Interest and Amortization	<u>\$238,000</u>
($0.06635 \times \$3,587,000$)	
TOTAL ANNUAL COST	\$238,000

These findings were presented at several workshop meetings with interested Federal, State and local officials and at a formal public meeting in Huntington, Massachusetts on 15 June 1976. General agreement was expressed on the desirability of providing additional storage at the Knightville project. The results of the investigation were then coordinated by letter with the appropriate Federal,

State and local officials and interested agencies and individuals. Letters of comment received in response to our letter are included in Appendix 2.

Initially, the plan to modify Knightville Dam was developed assuming that the City of Westfield would not provide the necessary items of local cooperation for the proposed Westfield Local Protection Project. However, in a letter dated 2 May 1977 the Mayor of Westfield wrote the Corps of his support for the local protection project (see Appendix 2). The loss of benefits from the area that would be protected in Westfield reduced the benefit-to-cost ratio of modifying the dam far below unity. For example, of the total \$277,500 in annual benefits allocated to providing additional storage at Knightville, \$238,600 is for the flood control function (\$224,400 for existing inundation reduction and \$14,200 due to growth in affluence) and \$38,900 is for area redevelopment. Construction of the Westfield project would reduce the flood control benefits by 96 percent or \$229,100. Following this reduction the remaining \$9,500 in flood control benefits plus \$38,900 in redevelopment benefits represent the total amount of annual benefits attributable to providing 8,640 acre-feet of additional flood control storage at the dam. On this basis an annual benefit of \$48,400 was compared to annual costs of \$238,000. This results in a benefit-to-cost ratio of 0.2 to 1.0 which clearly indicates that additional flood control storage at Knightville Dam cannot be economically justified after construction of the local protection project at Westfield. Accordingly, providing additional storage cannot be recommended and Alternative II, modifying the Knightville project to conform to update design criteria, is recommended for implementation. This modification, which can be accomplished utilizing operation and maintenance funds, is described in detail in the following section.

THE RECOMMENDED PLAN

The recommended plan provides for strengthening the existing spillway by installing a system of post-tensioned rock anchors as shown on Plate 3. Although the dam does not meet freeboard requirements, sufficient freeboard will be provided during a severe flood event by operation of the outlet gates.

PLAN ACCOMPLISHMENTS

The plan would insure that the Knightville project meets all current structural design criteria. In addition, the plan assumes that some time in the future the proposed Westfield Local Protection Project will be constructed, thereby protecting the majority of flood-prone property downstream of the dam.

EFFECT ON THE ENVIRONMENT

Potential changes in local conditions were considered in assessing the environmental impact of the proposed structural modification. The area that would be directly affected by construction activity would be limited to the existing spillway structure and the bedrock foundation. Some noise and dust would occur from drilling through the concrete and bedrock, but the rural setting would tend to minimize this impact.

Vehicle traffic would not be generated on local roads leading to the work area as no extensive transport of construction equipment is anticipated. Upon completion of the work, no visible change in the spillway structure will be apparent. In view of these minimal changes in local conditions, any environmental impacts resulting from the spillway modification are considered to be insignificant.

ECONOMICS OF RECOMMENDED PLAN

Inasmuch as the Corps is responsible for assuring the structural adequacy of its Civil Works structures, the recommended work does not require economic justification. However, intangible benefits including continued structural and operational adequacy would accrue to the proposed remedial measures.

COST

The cost estimate for the modification is based on November 1977 price levels and includes a 20 percent contingency factor. Engineering and design, and supervision and administration are estimated lump sum items and amount to about 17 percent. The estimated first cost of the modification is shown in the following tabulation:

ESTIMATED COST TO STRENGTHEN SPILLWAY

Item	Estimated Quantity	Unit	Unit Cost	Total Cost
Build and remove working platform	1	Job	L.S.	\$ 60,000
Drill holes for anchors	1	Job	L.S.	27,000
Install anchors and grout	1	Job	L.S.	<u>76,000</u>
SUB TOTAL				\$163,000
Contingencies 20% [±]				<u>33,000</u>
Total Construction Costs				\$196,000
Engineering and Design				14,000
Supervision and Administration				<u>20,000</u>
TOTAL FEDERAL COST				\$230,000

STATEMENT OF FINDINGS

This study has reviewed and evaluated all pertinent documents and the views of interested agencies and the concerned public with the intent of determining the feasibility of providing additional storage at Knightville Dam for additional flood control and other multiple use in the form of a recreational pool and low-flow augmentation. The structural and hydrologic adequacy of the existing project was also re-evaluated based on current criteria and conditions. The possible consequences of various alternatives have been studied for environmental, social well-being and economic effects, and engineering feasibility. In evaluating alternatives, the following points were considered pertinent:

- . Increase the degree of flood control in the lower Westfield River Valley.
- . Minimize adverse environmental effects.
- . Determine economic justification.
- . Maximize public health, safety and social well-being.
- . Insure that the existing project meets current design criteria.

I find that the proposed action is based on thorough analysis and evaluation of various practicable alternative courses of action for achieving the stated objectives. The recommended action is consonant with national policy, statutes and administrative directives and should best serve the interests of the general public.

ESTIMATED COST TO STRENGTHEN SPILLWAY

Item	Estimated Quantity	Unit	Unit Cost	Total Cost
Build and remove working platform	1	Job	L. S.	\$ 60,000
Drill holes for anchors	1	Job	L. S.	27,000
Install anchors and grout	1	Job	L. S.	<u>76,000</u>
SUB TOTAL				\$163,000
Contingencies 20% [†]				<u>33,000</u>
Total Construction Costs				\$196,000
Engineering and Design				14,000
Supervision and Administration				<u>20,000</u>
TOTAL FEDERAL COST				\$230,000

STATEMENT OF FINDINGS

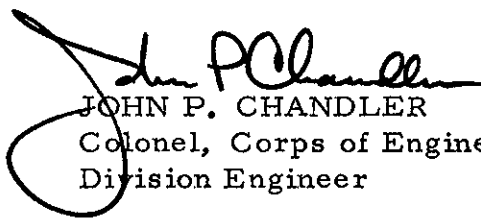
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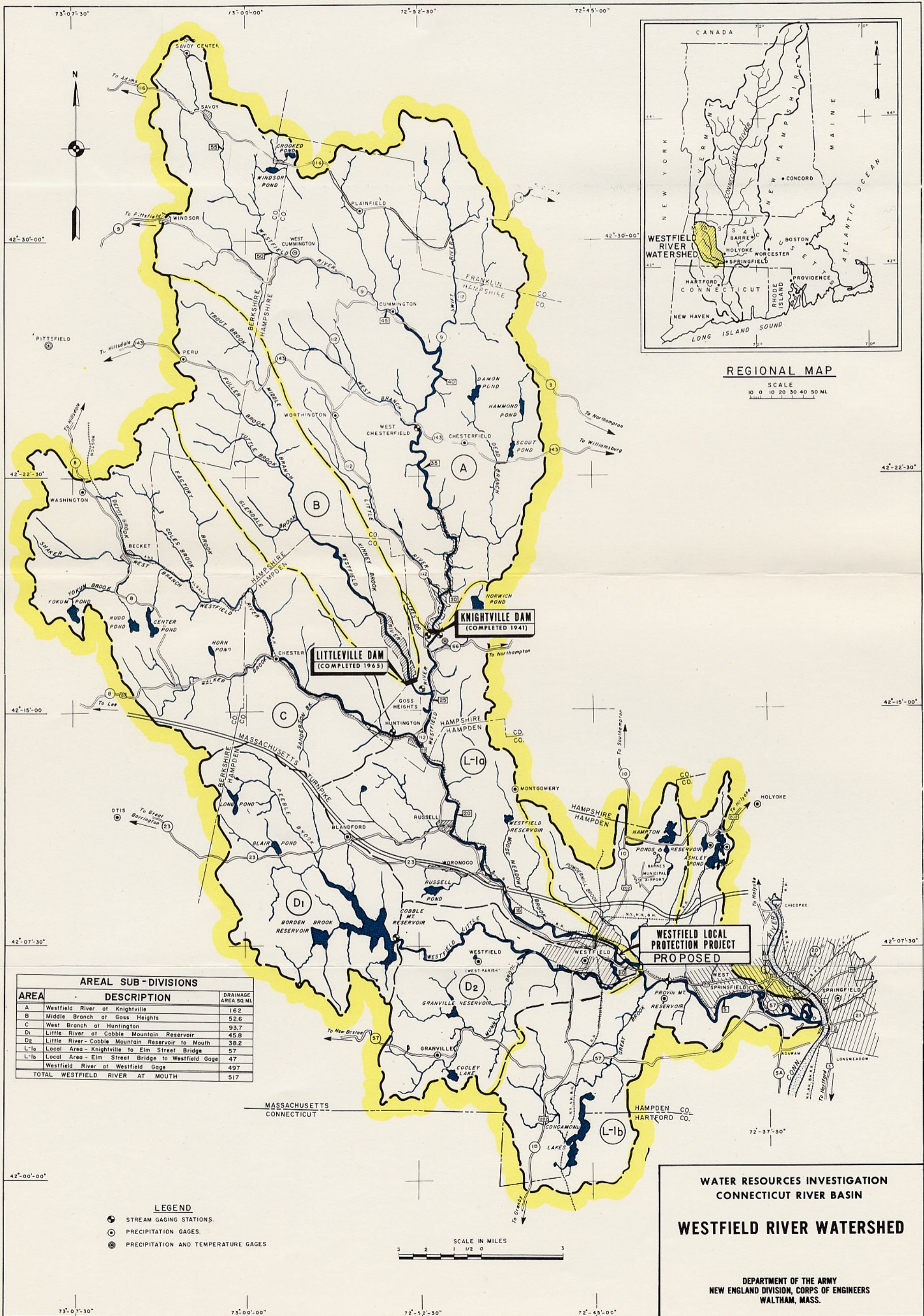
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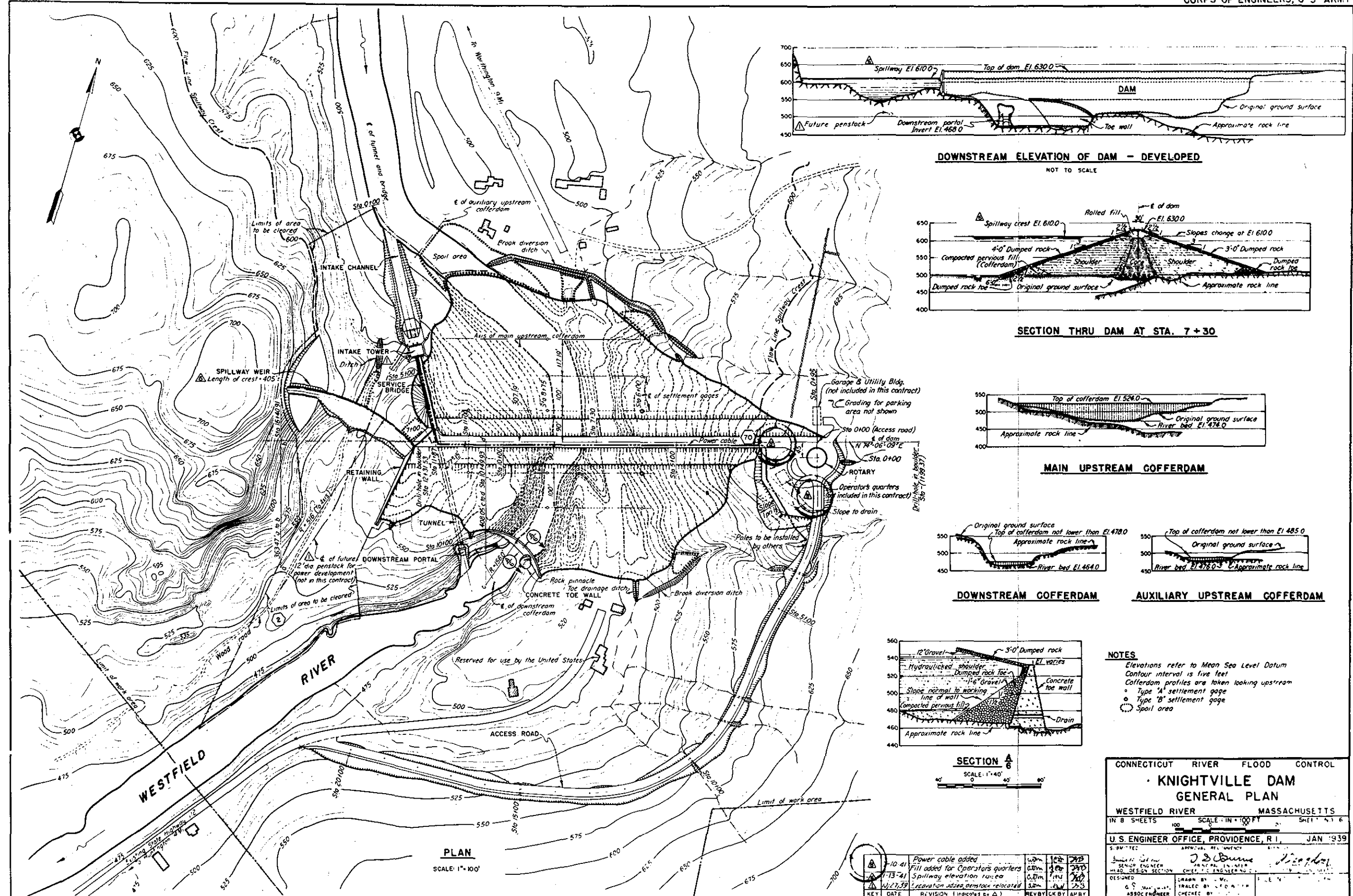
RECOMMENDATIONS

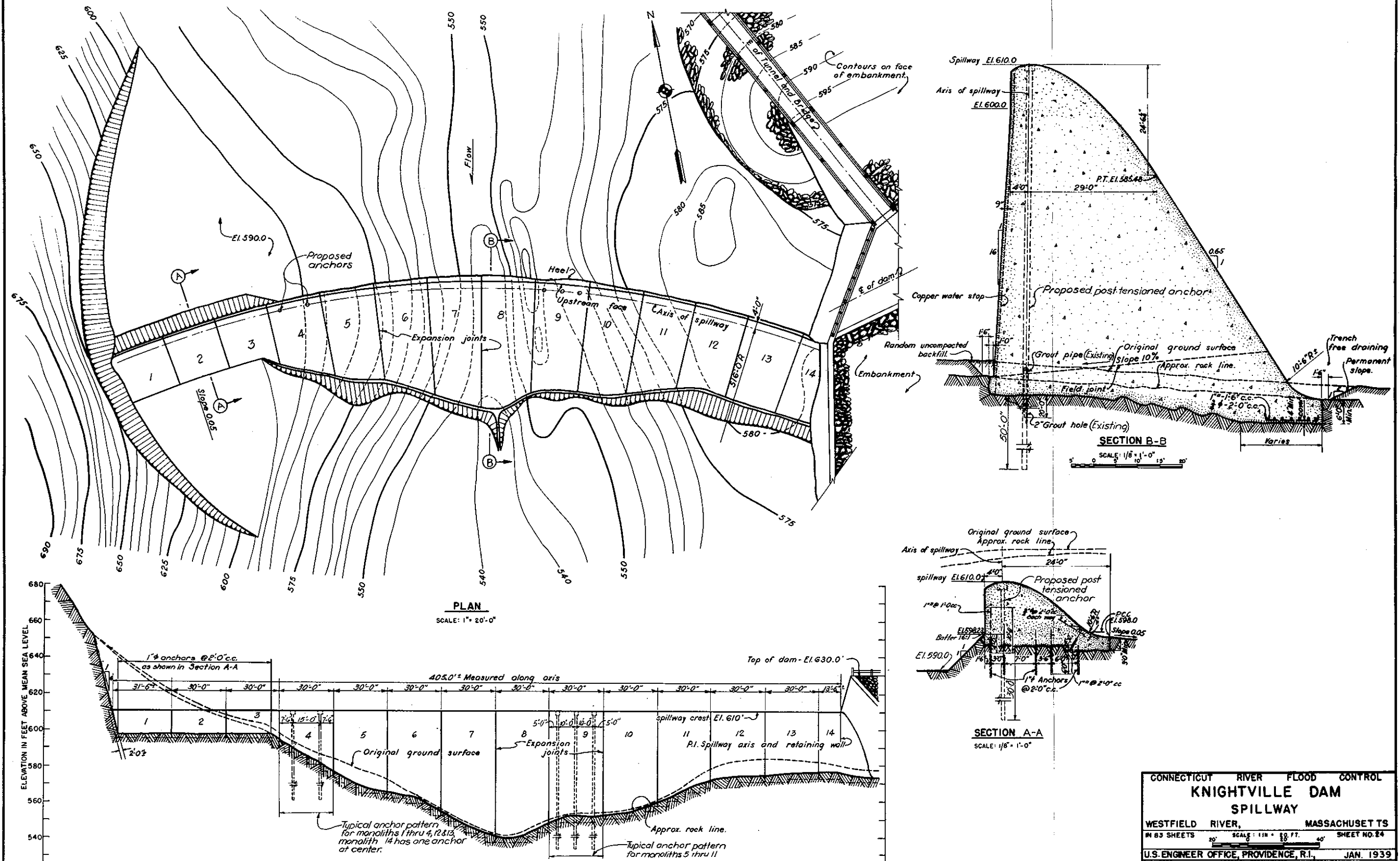
I recommend that funds in the amount of \$230,000 be provided to strengthen the existing spillway of Knightville as documented in this report and that this be accomplished under the Corps' normal operation and maintenance program. I further recommend that no modifications to Knightville Dam to provide storage for additional flood control, a permanent recreation pool, or for low-flow augmentation releases be adopted at this time due to a lack of economic justification and/or public support.



JOHN P. CHANDLER
Colonel, Corps of Engineers
Division Engineer

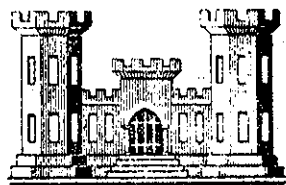






CONNECTICUT RIVER FLOOD CONTROL			
KNIGHTVILLE DAM			
SPILLWAY			
WESTFIELD RIVER,		MASSACHUSETTS	
IN 83 SHEETS	SCALE: 1 IN. = 80 FT.	SHEET NO. 24	
U.S. ENGINEER OFFICE, PROVIDENCE, R.I. JAN. 1939			
SUBMITTED		APPROVED	
HEAD, DESIGN SECTION		CHIEF, P.C. ENGINEERING DIV.	
DESIGNED BY: M.B.M.		TRACED BY: J.S.	
CHECKED BY: J.S.		FILE NO. CT. 1-1261	

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KNIGHTVILLE DAM MODIFICATION

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Feasibility

Report

For

WATER

RESOURCES

DEVELOPMENT

**KNIGHTVILLE DAM
MODIFICATION
FEASIBILITY REPORT
FOR
WATER RESOURCES DEVELOPMENT**

**HYDROLOGIC REVIEW
OF SPILLWAY AND
STORAGE CAPACITIES
AT KNIGHTVILLE DAM**

**PREPARED BY
CORPS OF ENGINEERS
NEW ENGLAND DIVISION
DEPARTMENT OF THE ARMY**

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HYDROLOGIC REVIEW OF SPILLWAY
AND STORAGE CAPACITIES AT
KNIGHTVILLE DAM

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HYDROLOGIC REVIEW OF SPILLWAY
AND STORAGE CAPACITIES AT
KNIGHTVILLE DAM

1. INTRODUCTION

This report presents a hydrologic review and analysis of the spillway and storage requirements for Knightville Dam and Reservoir located on the Westfield River in Huntington, Massachusetts. Spillway review included hydrologic studies comparing the original design analysis submitted to OCE in August 1940, with the latest criteria on probable maximum precipitation distribution and freeboard analysis, as set forth in Hydrometeorological Report 33 and Engineering Circular 1110-2-27, dated 1 August 1966, entitled, "Policies and Procedures Pertaining to Determination of Spillway Capacities and Freeboard Allowances for Dams". Unit hydrograph development for the spillway design flood was also updated through the analysis of recent floods. The review of flood control storage requirements referred to analysis of historic floods, operating experience at Knightville, high flow duration data, and comparative storage capacities at other flood control reservoirs in the basin. This report was prepared both as a planning aid and in response to OCE 1st Indorsement, date 7 March 1968. Re: "Review of Design Features of Existing Dams".

2. SUMMARY

The original spillway design flood for Knightville Dam, constructed in 1940, is somewhat smaller in magnitude than one developed using present day criteria. Also the storage capacity, equivalent to 5.7 inches of runoff, is somewhat less than that considered desirable for the control of large hurricane or snowmelt type floods in the mountainous regions of New England. Neither the spillway nor storage capacity at Knightville alone are considered sufficiently inadequate to pose a critical condition. It was concluded, however, that if a major rehabilitation or modification of the project is planned then increased spillway and storage capacity should be considered.

3. KNIGHTVILLE DAM

a. Authority. Knightville Dam was authorized as a project for the Westfield River basin in the Flood Control Act of 28 June 1938 (Public Law No. 761, 75th Congress) and set forth in House Document No. 455, 75th Congress, 2d session. Construction of the dam was initiated in August

1939 and completed in December 1941.

b. Project location. Knightville Dam is located in west-central Massachusetts on the main branch of the Westfield River, 4 miles north of the town of Huntington, Massachusetts and about 27.5 miles above the confluence of the Westfield and Connecticut Rivers in West Springfield, Massachusetts. The location of Knightville Dam is shown on plate 1.

c. Description of project. Major project components consist of a hydraulic earthfill dam, a concrete ogee weir spillway and outlet works. At spillway crest, Knightville Reservoir has a capacity of 49,000 acre-feet which is equivalent to 5.7 inches of runoff from a drainage area of 162 square miles. When filled to spillway crest, the reservoir is about 6 miles long with a surface area of 960 acres. A plan of the reservoir is shown on plate 2 and an area-capacity curve, on plate 3.

(1) Dam. The dam, shown on plate 4, consists of a hydraulic earthfill embankment 1,200 feet long with a maximum height of 160 feet above the riverbed. Top of the dam, at elevation 630 feet msl, has a width of 30 feet; with side slopes varying from 1 on 2.5 to 1 on 3.0.

(2) Spillway. The existing spillway, located on the right abutment adjacent to the dam, is an uncontrolled curved concrete ogee weir with a fixed crest at elevation 610 feet msl and a length of 400 feet. The spillway, shown on plate 4, was designed for a discharge of 91,000 cfs with maximum pool elevation 625 and a freeboard of 5.0 feet.

(3) Outlet works. The outlet works, located in the right abutment, consist of an intake channel 280 feet in length and a 16-foot diameter tunnel 605 feet long through rock. Discharge is controlled by three 6 x 12-foot broome gates mechanically operated from the gatehouse.

4. REFERENCES

Authorizing documents and past reports pertaining to the subject reservoir are listed below:

"308 Report" - A report, dated 28 February 1935, and printed as House Document 412, 74th Congress, 2d session.

"1937 Report" - A survey report, dated 20 March 1937, and printed as House Document 455, 75th Congress, 2d session.

"Analysis of Design for Knightville Dam" - A report by NED to Chief of Engineers, dated July 1939.

"Review of Spillway Requirements for Knightville Dam" - Report by NED to Chief of Engineers, dated August 1940.

"Review of Design Features of Existing Dams" - Report by NED to Chief of Engineers, dated May 1967.

5. FLOOD HISTORY

a. Historic floods. Damaging floods have occurred along the Westfield River and its tributaries since founding of the first settlements in the basin. Although there is little reliable information on the magnitudes of most of these early floods, available records indicate that the floods of October 1869 and December 1878 were severe and caused considerable damage. The 1878 flood occurred on 10 December when 6 to 8 inches of snow fell on frozen ground, followed by rain and rapidly rising temperatures, and produced an exceedingly high rate of runoff. A great amount of damage occurred throughout the valley, particularly at Westfield. Other known floods in the Westfield River basin prior to 1900 were March 1776, September 1826, February 1840, January 1841, April 1843, May 1854, April 1862, April 1869, September 1879, January 1880, April 1895, and March 1896.

b. Recent floods. Reliable records of flood stages in the Westfield River watershed have been maintained since 1909. Minor floods are frequent in the basin usually due to intense rainfall, melting snow, or a combination of both. Floods develop very rapidly in the basin and experience gained from regulation of Knightville Dam and Littleville Lake indicates that floods on the principal branches of the Westfield River crest about 4 hours after intense rainfall. At Westfield, the time of concentration is about 8 hours following heavy precipitation. Six major floods have occurred in the basin since 1927, and are briefly described in the following paragraphs.

(1) November 1927. Rainfall in the previous month was almost double the normal amount, saturating the ground and filling the streams and ponds. A flood resulted from approximately 6 inches of rain which fell on previously saturated ground almost continually from 26 to 30 hours between 2-4 November over the Westfield basin.

(2) March 1936. From 9 to 13 March heavy rainfall combined with relatively high temperatures caused a portion of the snow blanket to melt resulting in high runoff. This broke up the ice cover on the rivers and serious ice jams occurred in the lower section of the basin.

A second rain storm of greater intensity occurred on 18 and 19 March, melting the remaining snow blanket and causing the already swollen

ivers to overflow their banks. Total rainfall for the two events averaged about 8 inches.

(3) September 1938. The second most damaging flood of record resulted from torrential rainfall accompanying a tropical hurricane which swept over New England. Flood stage on the Westfield River exceeded that of the 1936 flood by almost 3 feet at several places. The principal cause of flooding was a 4-day storm totaling 10 to 12 inches of rainfall on ground which had been saturated by rains earlier in the month, and reaching its greatest intensity during the night of 20 September.

(4) December 1948. This event resulted from heavy rains averaging about 9 inches and falling on frozen ground, with runoff augmented by some snowmelt. Knightville Dam, constructed in 1941, was completely filled during this flood.

(5) August 1955. The maximum flood of record was caused by three storm centers which passed over Massachusetts, one of them directly over the Westfield River basin. Heavy rains, totaling almost 20 inches around Westfield, fell on ground already saturated by 6 to 9 inches of rain during the previous week. The combination of saturated soil, relatively high level of streams, and great intensity of rainfall produced major flooding throughout the lower basin.

(6) October 1955. This flood was caused by a slow-moving continental storm passing over New England and depositing up to 13 inches of rain in the basin. The Knightville Reservoir was almost completely filled during this flood.

6. RESERVOIR REGULATION

Since completion of Knightville Dam in December 1941, there have been about 60 significant reservoir operations, with the five most notable operations as follows:

<u>Date of Flood</u>	<u>Storage Utilized in Percent</u>
December 1948	100
March 1953	68
August 1955	58
October 1955	96
April 1960	60

7. UNIT HYDROGRAPHS

Unit hydrographs were developed through analysis of computed inflows

to Knightville for four significant record floods. Data pertinent to the derivation of the unit hydrographs are shown on plate 5. Precipitation records were taken from several stations within the basin, namely, Knightville, Chesterfield, Worthington, Cummington, West Cummington and Plainfield. Location of these stations are shown on plate 1.

Individual analysis of the two recent floods of March 1951 and August 1955 are shown on plates 6 through 9. Using computer program 23-J2-L-211, developed by the Hydrologic Engineering Center, Davis, California, entitled: "Unit Hydrograph and Loss Rate Optimization," a composite 3-hour unit hydrograph was developed from four floods - September 1938, November 1950, March 1951 and August 1955. The 3-hour unit hydrograph for each storm and the composite one are shown on plate 5.

To reflect the higher runoff rates to be expected from a major flood, as recommended in EM 1110-2-1405, "Flood Hydrograph Analysis and Computations," the composite unit hydrograph peak was increased by 25 percent to a peak of 11,000 cfs (68 csm). A comparison of this peaked 3-hour unit hydrograph and the 6-hour unit hydrograph used in the original design (1940 study) for Knightville Dam is shown on plate 10. In the original design (1940 study), the developed 6-hour unit hydrograph peak of 6,900 cfs was increased 70 percent, resulting in a peak of 11,700 cfs. Unit hydrographs and spillway design flood peaks for other comparable sized reservoir projects in New England are listed in table 1.

8. PROBABLE MAXIMUM PRECIPITATION

Values of rainfall for the probable maximum storm were obtained from Hydrometeorological Report 33, "Seasonal Variations of Probable Maximum Precipitation, East of the 105th Meridian," prepared by the Hydrometeorological Section of the U.S. Weather Bureau, and adjusted for the Knightville Dam drainage area of 162 square miles, as described in EC 1110-2-27.

From figure 1, Report 33, an index rainfall of 20.4 inches was selected as the 200-square mile, 24-hour probable maximum precipitation (PMP) and the resulting PMP for 162 square miles was 21.2 inches. However, to correct for the improbability of the storm centering itself over the 162-square mile drainage area the PMP rainfall was reduced 12 percent. The rainfall associated with each time period of 6, 12 and 24 hours for a drainage area of 162 square miles is shown in the following tabulation:

TABLE 1
HYDROGRAPH PEAKS

<u>Project</u>	<u>Drainage Area (sq. mi.)</u>	<u>3-Hour Unit Hydrograph Peak</u>		<u>Spillway Design Flood Peak Inflow</u>	
		<u>CFS</u>	<u>CSM</u>	<u>CFS</u>	<u>CSM</u>
Townshend Dam (West River)	106	10,900	103	190,000	1,790
Colebrook Dam (West Branch Farmington River)	118	11,000	93	165,000	1,400
North Springfield Dam (Black River)	158	11,000	70	157,000	995
North Hartland Dam (Ottauquechee River)	220	17,160	78	199,000	900
Littleville Dam (Middle Branch Westfield River)	52.3	8,000	115	98,000	1,870
Knightville Dam (Westfield River)	162	8,800	54	-	-
	- (+25%)	11,000	68	145,000	895
	- (+50%)	13,200	82	165,000	1,020

<u>Duration</u> (hours)	<u>Percent</u> <u>of Index</u> <u>Rainfall</u>	<u>Probable</u> <u>Maximum</u> <u>Precipitation</u> (inches)	<u>12 Percent</u> <u>Reduction</u> <u>Factor</u> (inches)	<u>Spillway</u> <u>Design</u> <u>Storm</u> (inches)
6	78	15.90	1.90	14.00
12	92	18.80	2.30	16.50
24	104	21.20	2.54	18.66

Three-hour amounts of precipitation, losses and rainfall excess arranged into a critical storm pattern, are shown in table 2. The most intense 6-hour rainfall total was subdivided into two 3-hour amounts, placing 67 percent of the 6-hour total in one 3-hour period and 33 percent in the other. Rainfall during the remaining 6-hour periods was assumed to be uniform. Losses from infiltration, surface detention and transpiration were assumed at a rate of 0.15 inch per 3-hour period, the minimum loss rate expected during such a storm with very high antecedent moisture conditions. The resulting total 24-hour excess rainfall was 17.5 inches compared with a total of 15.6 inches in the original design.

TABLE 2

PROBABLE MAXIMUM PRECIPITATION

<u>Time</u> (hours)	<u>Maximum</u> <u>Precipitation</u> (inches)	<u>Losses</u> (inches)	<u>Rainfall</u> <u>Excess</u> (inches)	<u>1940</u> <u>Design Rainfall</u> <u>Excess</u>	<u>Rainfall</u> <u>Pattern</u> (inches)
0	0	0	0		0
3	9.40	0.15	9.25		0.49
6	4.60	0.15	4.45	9.0	1.10
9	1.26	0.15	1.11		4.45
12	1.25	0.15	1.10	3.8	9.25
15	.65	0.15	0.50		1.11
18	.64	0.15	0.49	1.9	0.50
21	.43	0.15	0.28		0.28
24	.43	0.15	0.28	0.9	0.28
Total	18.66	1.20	17.46	15.6	17.46

9. SPILLWAY DESIGN FLOOD

The spillway design flood inflows to Knightville Dam were derived by applying the rainfall excess values of table 2 to the previously

discussed spillway design unit hydrographs. The resulting inflow hydrographs were then routed through the reservoir to determine maximum surcharges. It was determined that with a spillway length of 400 feet, with storage initially filled to spillway crest, and outlet gates inoperative, the resulting maximum surcharge elevation was 629 feet msl. Whereas, increasing the unit hydrograph peak 50 percent instead of 25 percent the resulting maximum surcharge was 630.3 feet msl or 1.3 feet higher.

This comparative analysis demonstrated that the increase in surcharge was well within the adopted freeboard of 5 feet and that the project surcharge was not overly sensitive to the magnitude of the unit graph peak. The unit hydrograph which was increased 25 percent was therefore considered sufficiently conservative and was adopted for all further studies. The spillway design flood is presented on plate 11.

10. SURCHARGE-LENGTH CURVES

Spillway surcharge-length curves shown on plate 12 were developed through successive routings of the spillway design inflow hydrograph through the reservoir with a range of spillway lengths. For these routings it was assumed that the outlet gates would remain closed until the surcharge reached 10 feet. The gates would then be opened 50 percent and completely opened when the surcharge reached 12 feet, giving priority consideration to the safety of the dam. Assuming the project unattended or the gates inoperable, as recommended in EC 1110-2-27, was considered an unreasonably severe criteria in view of the fact that the reservoir is assumed initially 50 percent full. If it were assumed the outlets remained closed throughout the flood, the resulting maximum surcharge would be increased about 1.3 feet.

Further comparative routings were made assuming various amounts of storage initially utilized in the reservoir as a result of previous storms. With an empty reservoir and outlet operable, surcharge attained with existing spillway height and length was 625.4 feet msl. With a reservoir one-half full the maximum water surface was 627.3 and full, the maximum water surface elevation was 627.7 feet msl.

Following procedures outlined in EC 1110-2-27, comparisons were made of the required height of dam resulting from: (a) starting with the reservoir 50 percent filled (reference level "c") and adding 5 feet of freeboard, or (b) starting with a full pool (reference level "b") and adding 3 feet of freeboard. In all cases the maximum height, and therefore the governing criteria, resulted when starting with reference level "c" and adding 5 feet of freeboard to the surcharge.

11. FREEBOARD ANALYSIS

The effective fetch distance for Knightville Dam was developed following procedures set forth in ETL 1110-2-8, dated August 1966. Wave height, runup and wind setup as determined from EC 1110-2-27, were as follows:

Wave height	1.4 feet
Runup	1.8 feet
Wind setup	0.2 foot

Winds producing maximum waves and setup on the slopes of Knightville Dam would have to be from the northerly direction due to the orientation and shape of the reservoir. Information on maximum wind velocities and direction at Hartford, Connecticut (which is the nearest long term station) for 15 years of record is shown in table 3.

A maximum effective fetch distance of 0.50 mile together with wind velocity of 40 miles per hour were used in computing wave heights. The resulting wave height was less than 5 feet so the minimum freeboard of 5 feet with freeboard reference level "c" was adopted as the present day criteria for determining height of dam.

TABLE 3

MAXIMUM WINDS AT
HARTFORD, CONNECTICUT

Elevation 169 Feet msl
15 Years of Record

<u>Date</u>	<u>Fastest Mile</u> (mph)	<u>Direction</u>
February 1967	53	SW
November 1955	51	W
March 1956	50	NE
January 1964	50	NW
December 1955	49	NW
April 1956	47	NE
June 1957	45	W
August 1955	44	NW
September 1960	43	NE
May 1957	41	NW
October 1955	40	W
July 1966	35	NW

12. SPILLWAY ADEQUACY

Comparative data between the original (1940) spillway design flood analysis and present day criteria is listed in the following table:

TABLE 4
COMPARATIVE SPILLWAY FLOOD DATA

	<u>Original Design Criteria (1940)</u>	<u>Current Criteria</u>	
Initial Pool Condition	Full	Full	one-half full
Initial Pool Elev. (ft, msl)	610	610	580
Spillway Length (ft)	400	400	400
Outlet Gates	Closed	Operable	Operable
Excess Runoff (inches)	15.6	17.5	17.5
Peak Inflow (cfs)	113,200	145,000	145,000
Peak Outflow (cfs)	91,000	131,000	127,000
Spillway Coefficient	3.9	3.84	3.83
Surcharge (feet)	15	17.7	17.3
Freeboard (ft)	5	3	5
Required Top of Dam (elev)	630	630.7	632.3

The results of this study demonstrated that the present spillway at Knightville Dam does not meet capacity requirements of current design criteria. The spillway design flood developed in this study would not overtop the dam but would encroach 2.3 feet on the original 5 feet of freeboard resulting in a remaining freeboard of only 2.7 feet. Although the discharge capacity of the spillway is inadequate on the basis of present hydrologic criteria, no critical or emergency condition exists. However, it is concluded that when a major modification or rehabilitation is planned for the project consideration be given to increased spillway capacity.

Freeboard requirements can be met by either increasing the length of the spillway or raising the height of dam, or a combination of both. The relationship between spillway length and required height of dam is illustrated on plate 12.

13. FLOOD CONTROL STORAGE

It has been established that flood control storage equivalent to 6 to 8 inches of runoff from the contributing watershed is needed in the

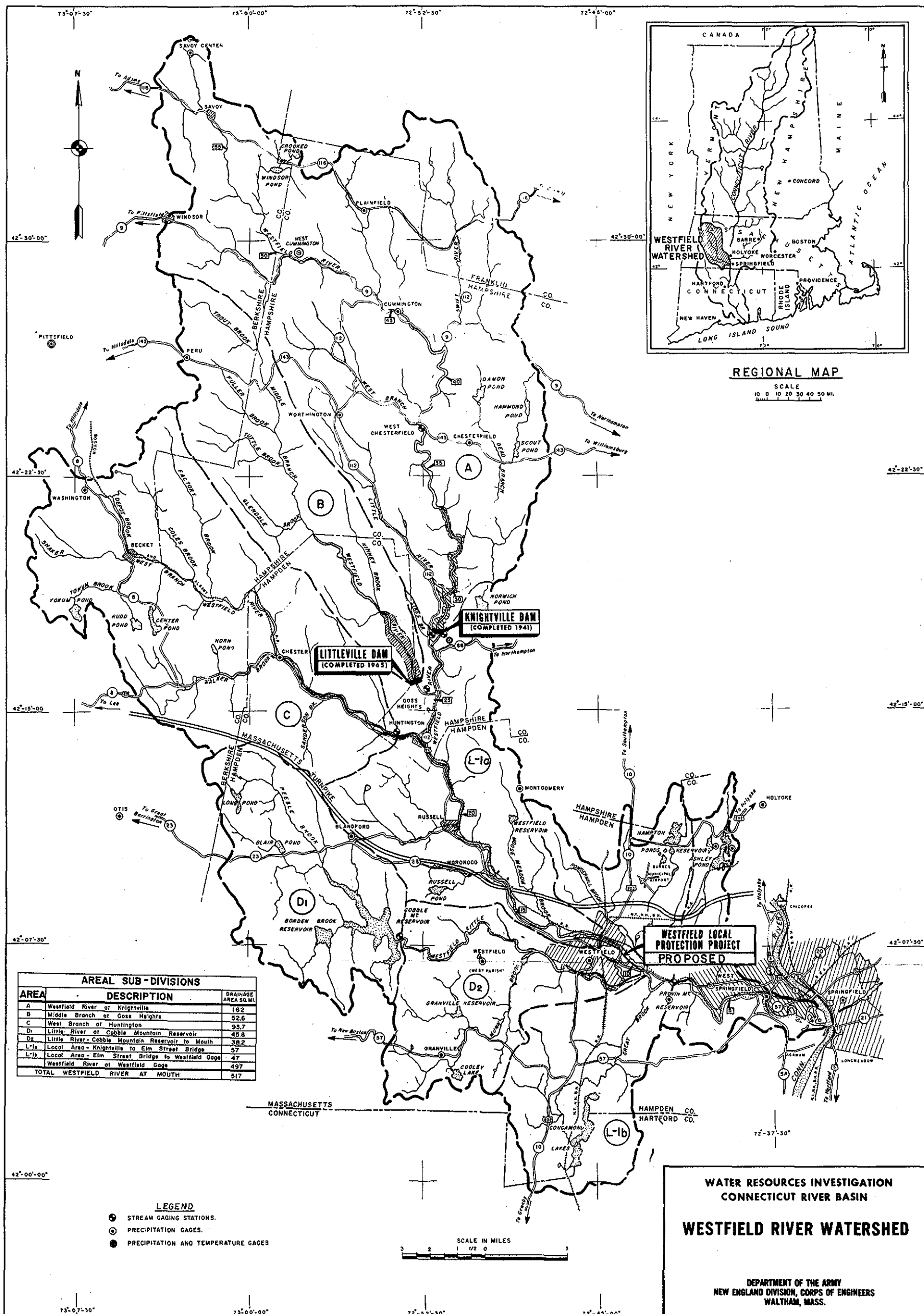
Berkshire Mountain regions of Massachusetts to provide a high degree of control during hurricane or large volume snowmelt floods. Storage requirements for flood control in the Connecticut River basin were discussed in Appendix C of Comprehensive Water and Related Land Resources Investigation Connecticut River Basin," June 1970.

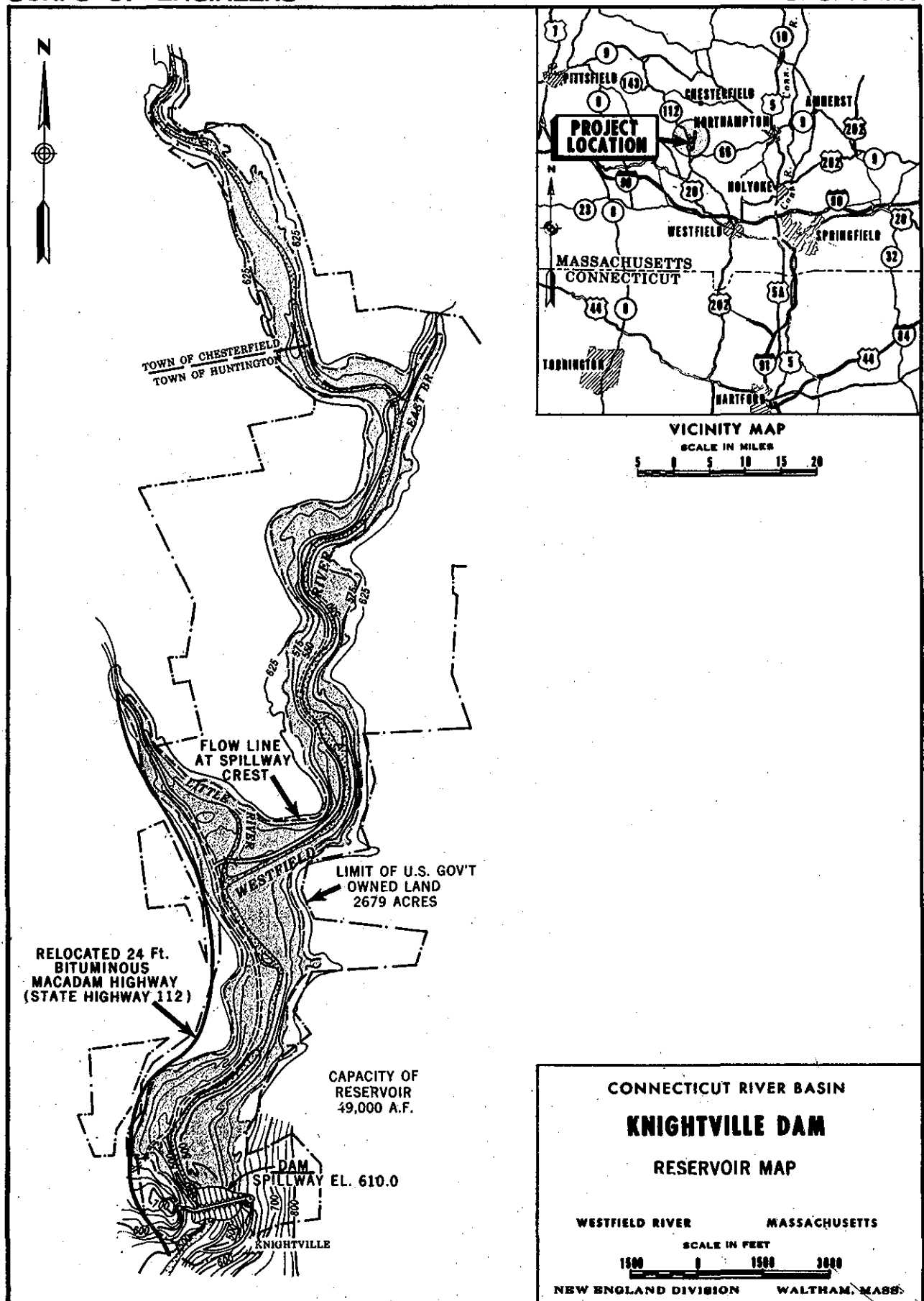
The average storage capacity of all 16 Corps reservoirs in the Connecticut River basin is 7.0 inches. Knightville reservoir with 49,000 acre-feet of flood control storage, equivalent to 5.7 inches of runoff, is about 20 percent below the average. During its 35 years of operation Knightville storage was filled to 100 percent and 96 percent of capacity in 1948 and 1955, respectively.

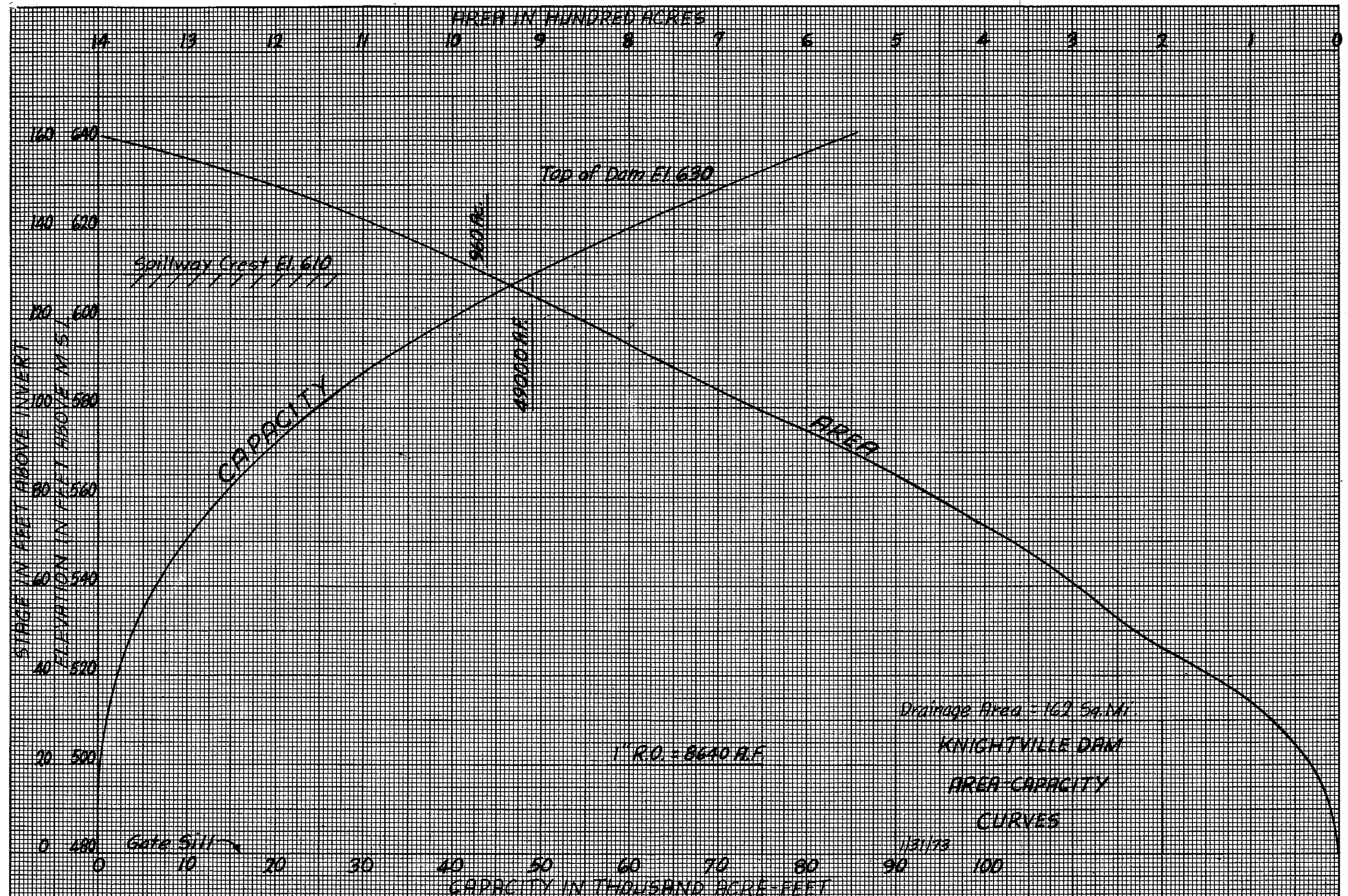
Factors affecting the storage required for flood control at different locations are: the length of time reservoir releases may have to be shut off during major floods (related to reservoir location and degree of watershed control), travel times and runoff characteristics of the region and safe channel capacities downstream of the project.

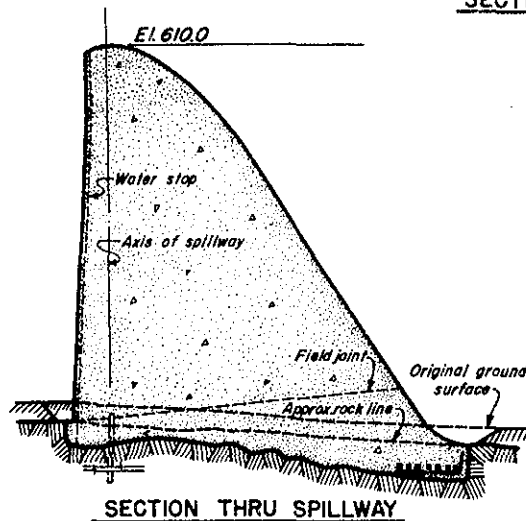
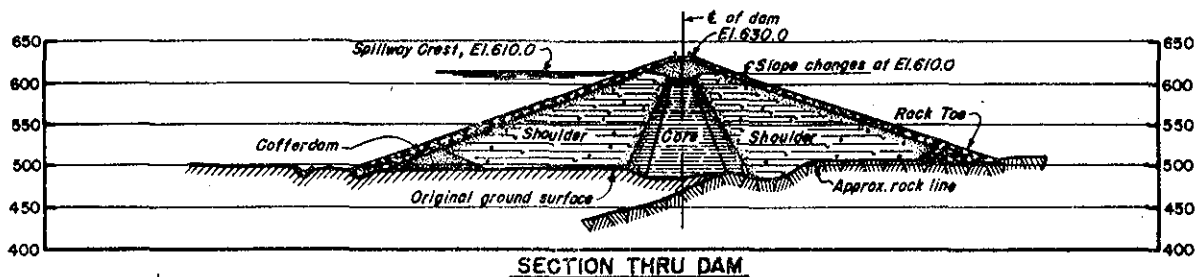
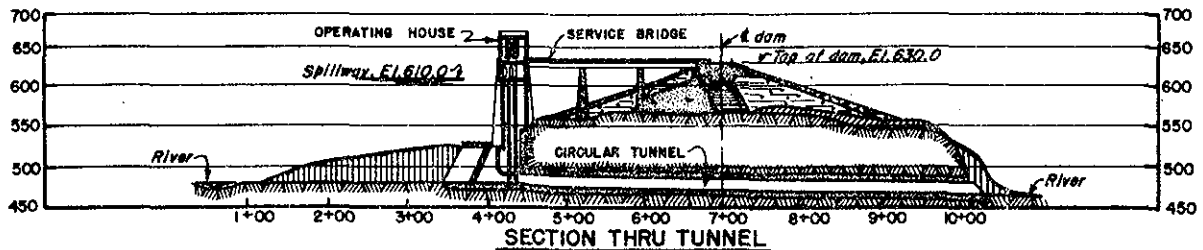
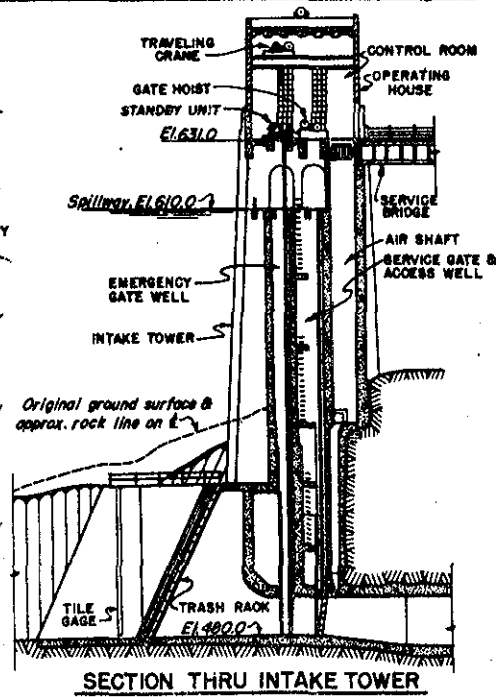
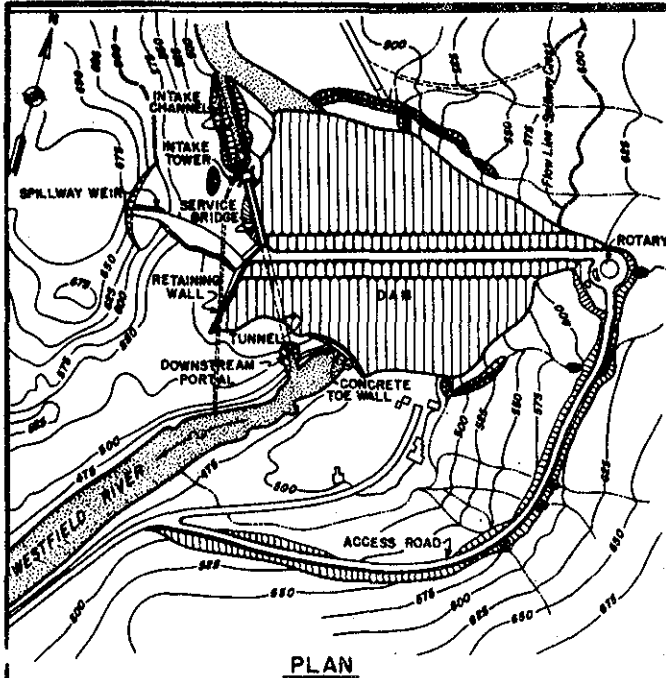
The relative flood control effectiveness of varying amounts of flood control storage at Knightville were estimated for economic purposes. Percent Effective versus Frequency curves were derived by analysis of high flow duration frequency data for the West Branch of the Westfield River. These curves are shown on plate 13. The relative effectiveness was based on the amount of storage required to completely store the 3-day duration high flow for various frequencies. The 3-day duration value was selected based on hydrologic studies of past floods and 35 years of operational experience.

From a hydrologic point of view it was concluded that the 5.7 inches of storage at Knightville was not seriously deficient and it, in itself, did not warrant major action. However, it is recommended that in planning any major modification to the project that consideration be given to increased flood control storage. Additional storage will provide greater operational flexibility during prolonged snowmelt floods or during a series of unusual storm events. Stored floodwaters could be held for longer periods with less chance of exhausting storage capacity, thereby providing optimum regulation for maximum possible effectiveness.









CONNECTICUT RIVER BASIN

KNIGHTVILLE DAM

PLAN & SECTIONS

WESTFIELD RIVER

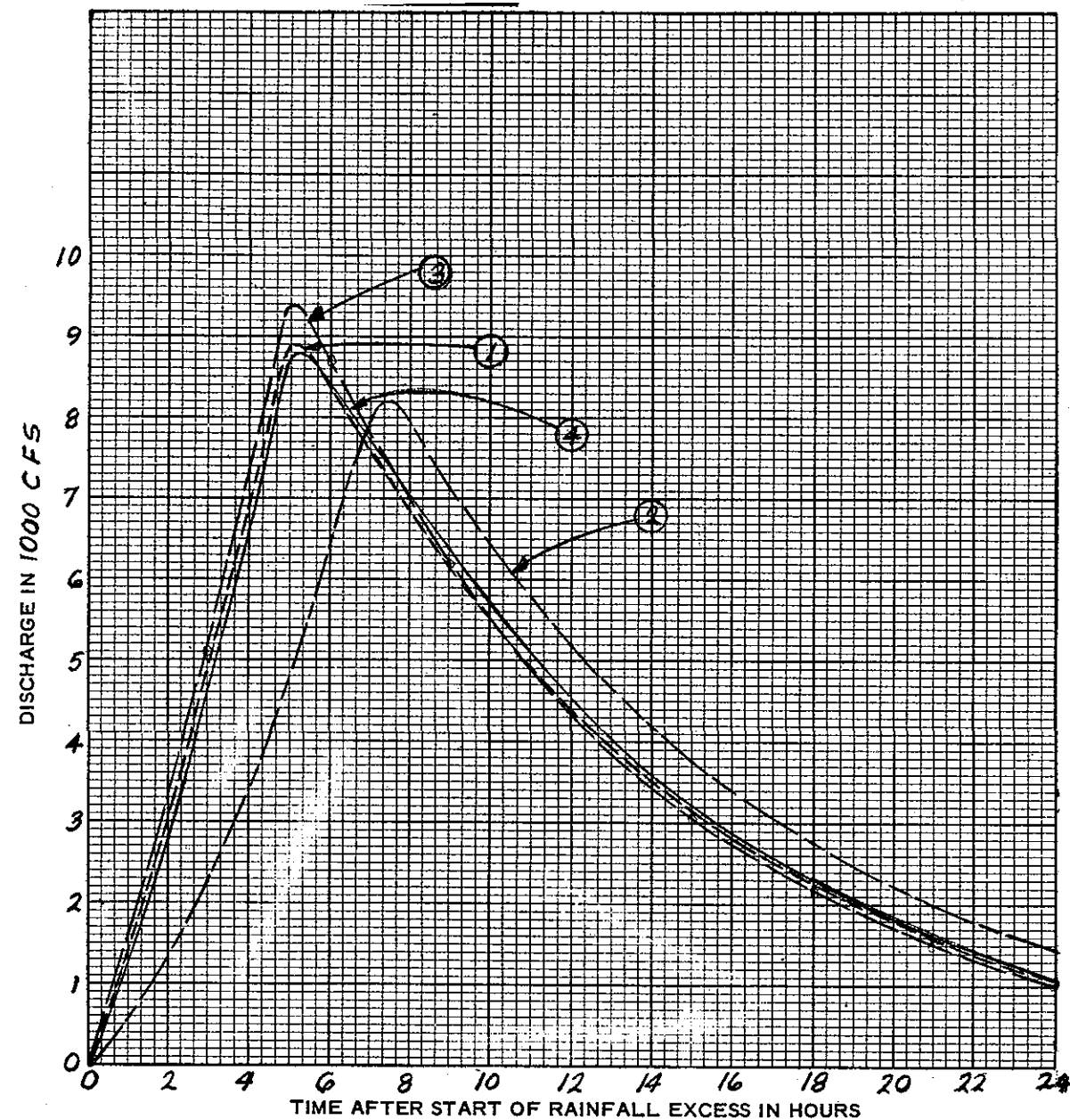
MASSACHUSETTS

NOT TO SCALE

NEW ENGLAND DIVISION

WALTHAM, MASS.

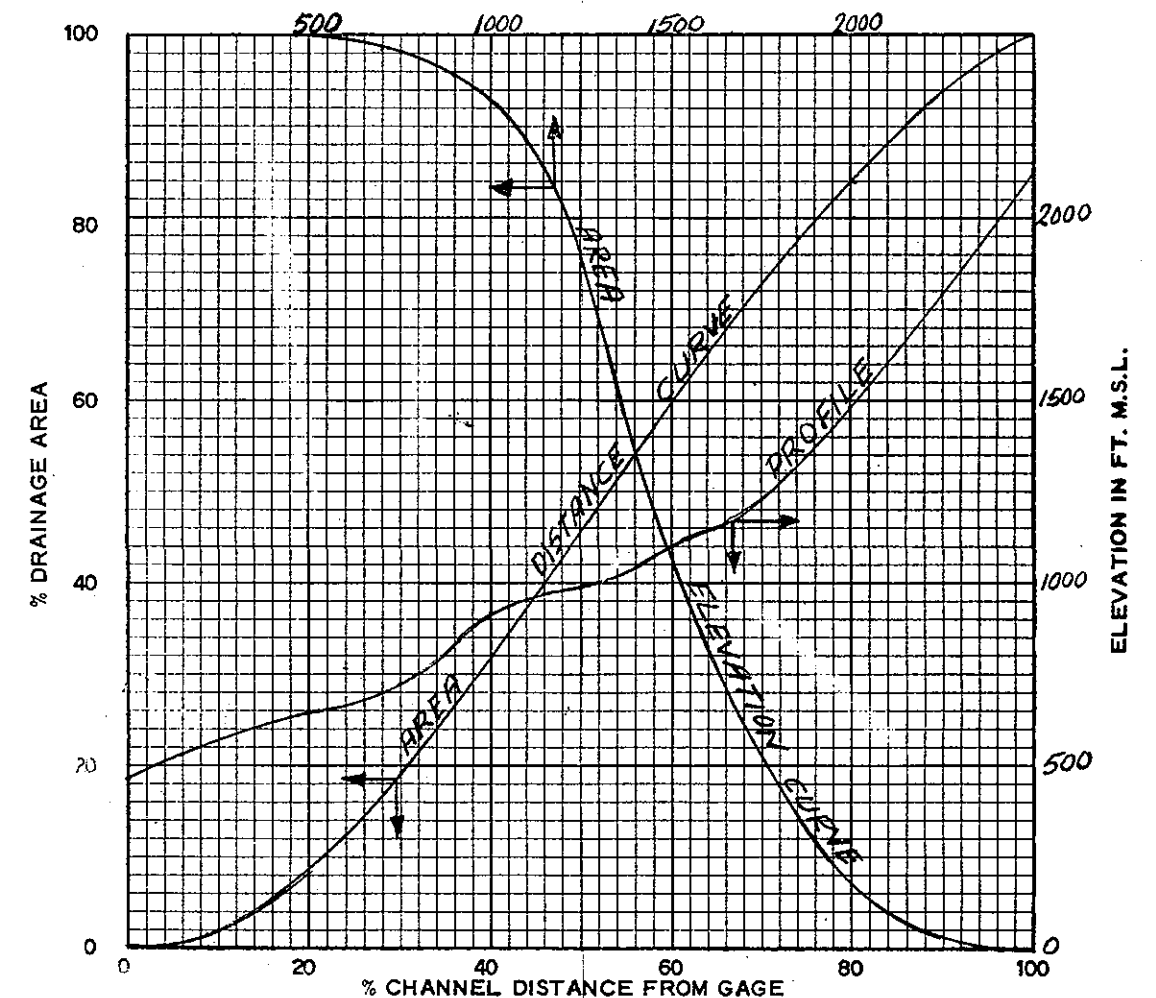
3-HOUR UNIT HYDROGRAPHS



DATA FROM OBSERVED UNIT HYDROGRAPHS															
DATE OF RAINFALL	LEGEND	AVE. P (in.)	RAINFALL EXCESS		L_{cp} (mi.)	STAGE RECORD	Q_{pR} (c.f.s.)	Q_p hrs. (c.f.s.)	t_{pR} (hr.)	t_p (hr.)	t_v (hr.)	C_{tR}	C_{p640}	K_m (hr.)	T_c (hr.)
			DURATION (hr.)	AMOUNT (in.)											
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Sept. 21-22, 1938	---	①	6	2.58		Rec.	12,500	8900	3.1	3.5	7.6	0.492	315		
March 29-31, 1951	---	②	15	1.32		Rec.	7600	8200	6.0	6.8	8.6	0.920	281		
Aug. 18-19, 1955	---	③	9	1.62		Rec.	8800	9400	3.4	3.3	7.0	0.520	182		
Computed Optimum	---	④	3	1.0		---	---	8800	---	3.7	---	---	---		

DRAINAGE AREA CHARACTERISTICS					
DRAINAGE AREA	162	sq. mi.	L	31.2	mi.
MAXIMUM ELEVATION	2505	ft. m.s.l.	L_{ca}	16.8	mi.
MINIMUM ELEVATION	470	ft. m.s.l.	$(LL_{ca})^{0.3}$	6.54	
MEAN ELEVATION (weighted)	1460	ft. m.s.l.	DRAINAGE DENSITY	—	mi. / sq. mi.
LAND SLOPE	—	ft. / mi.	MAP SCALE	1: 62,500	
MAIN STREAM SLOPE	44	ft. / mi.	METHOD OF FLOW SEPARATION	—	
			BASIN SHAPE FACTOR	6.01	

ELEVATION IN FT. M.S.L.

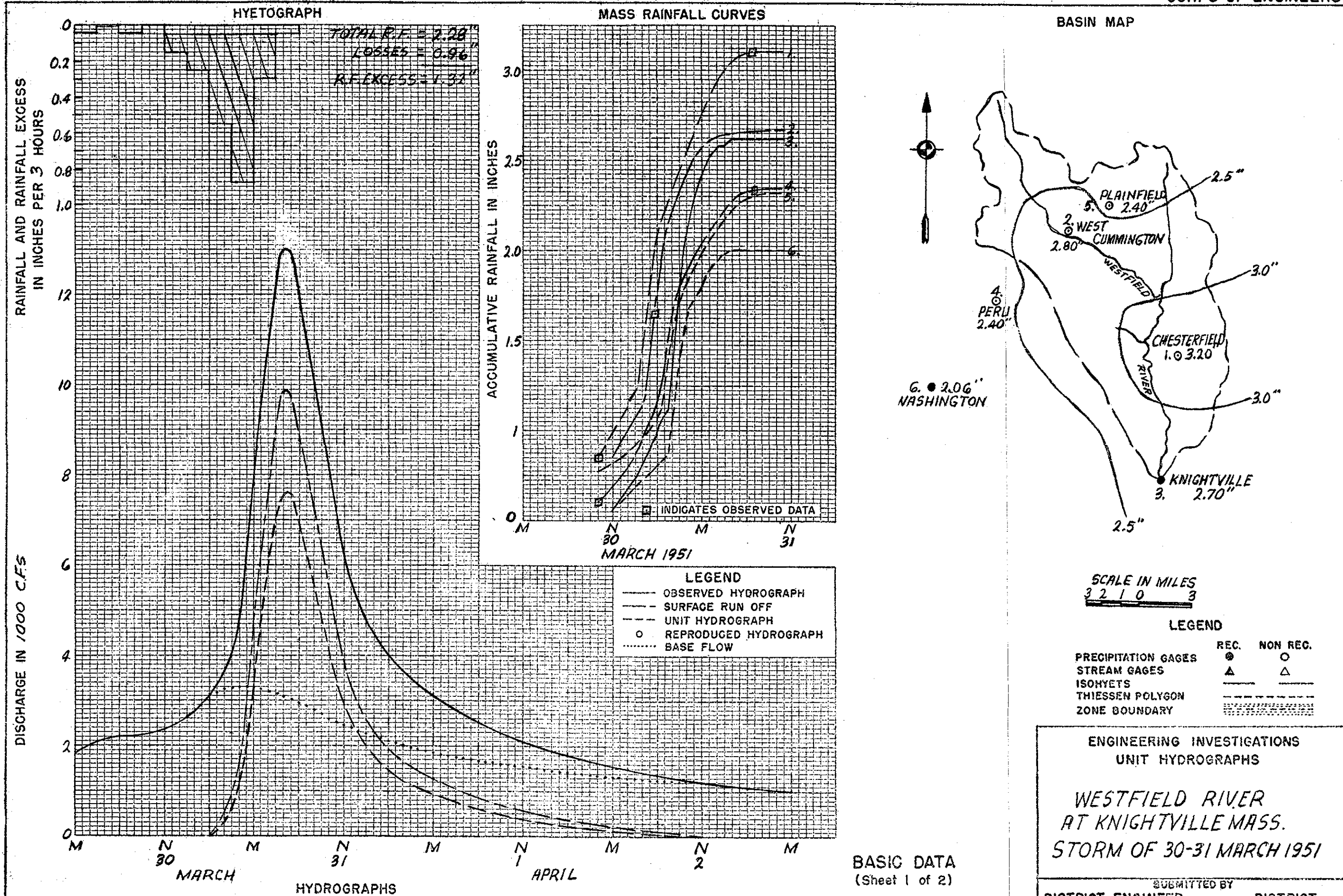


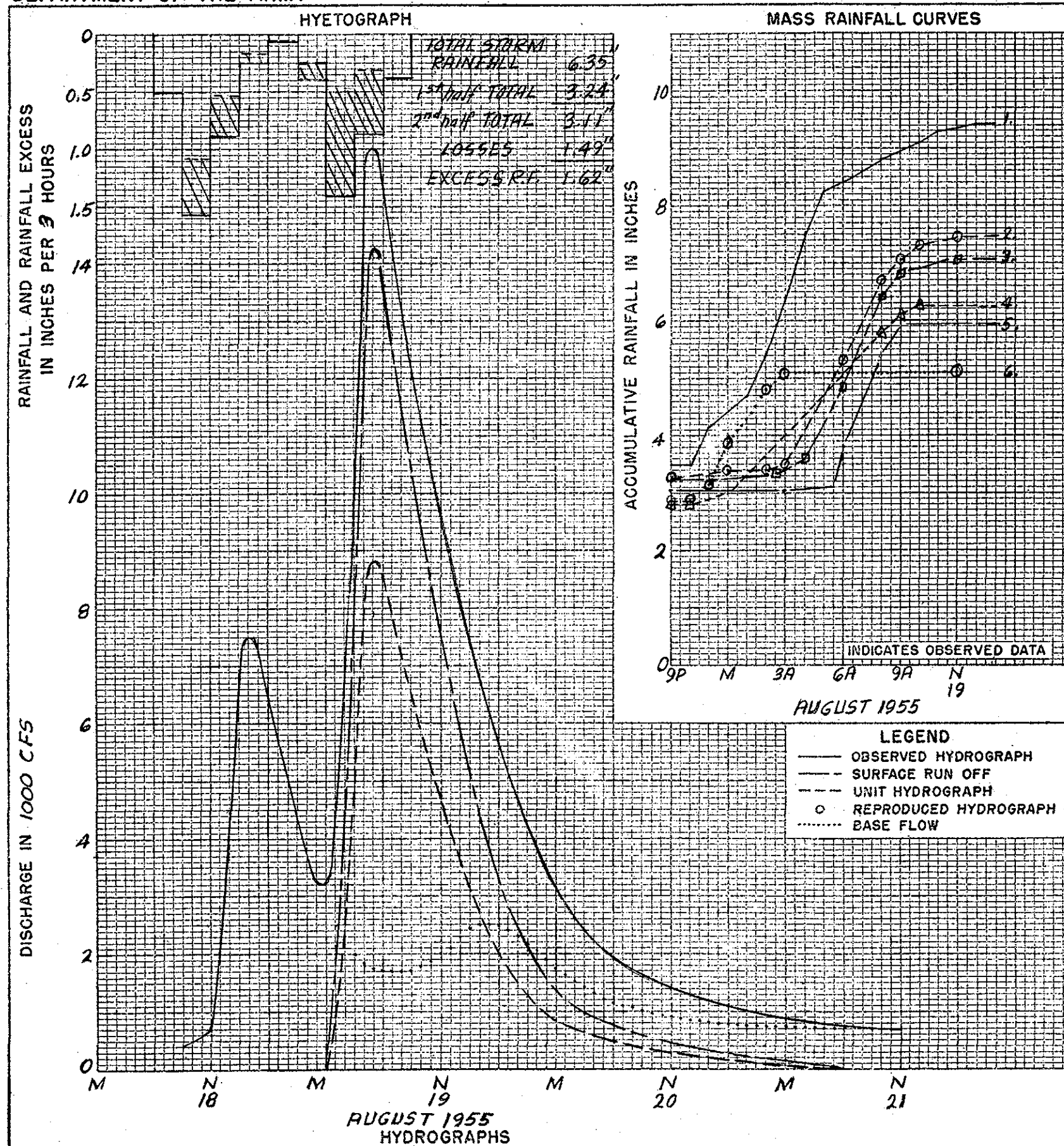
ENGINEERING INVESTIGATIONS
UNIT HYDROGRAPHS

WESTFIELD RIVER
AT KNIGHTVILLE, MASS.

PERTINENT DATA

SUBMITTED BY
DISTRICT ENGINEER, DISTRICT





UNIT HYDROGRAPH BASIC DATA SHEET

(7) STREAM AND STATION WESTFIELD RIVER AT KNIGHTVILLE LAT. 42°-17'-16" LONG. 72°-51'-53"

(8) DATE OF STORM 19-20 AUGUST 1955 (9) OFFICE NEW ENGLAND DIVISION

(10) DRAINAGE AREA 162 SQ. MI. (11) L 31.20 MI. (12) L_{ca} 16.80 MI. (13) $(L_{ca})^{0.3}$ 6.54

(14) AVERAGE RAINFALL _____ IN. (15) t_R 9 HRS. (16) DIRECT RUNOFF 1.62 IN.

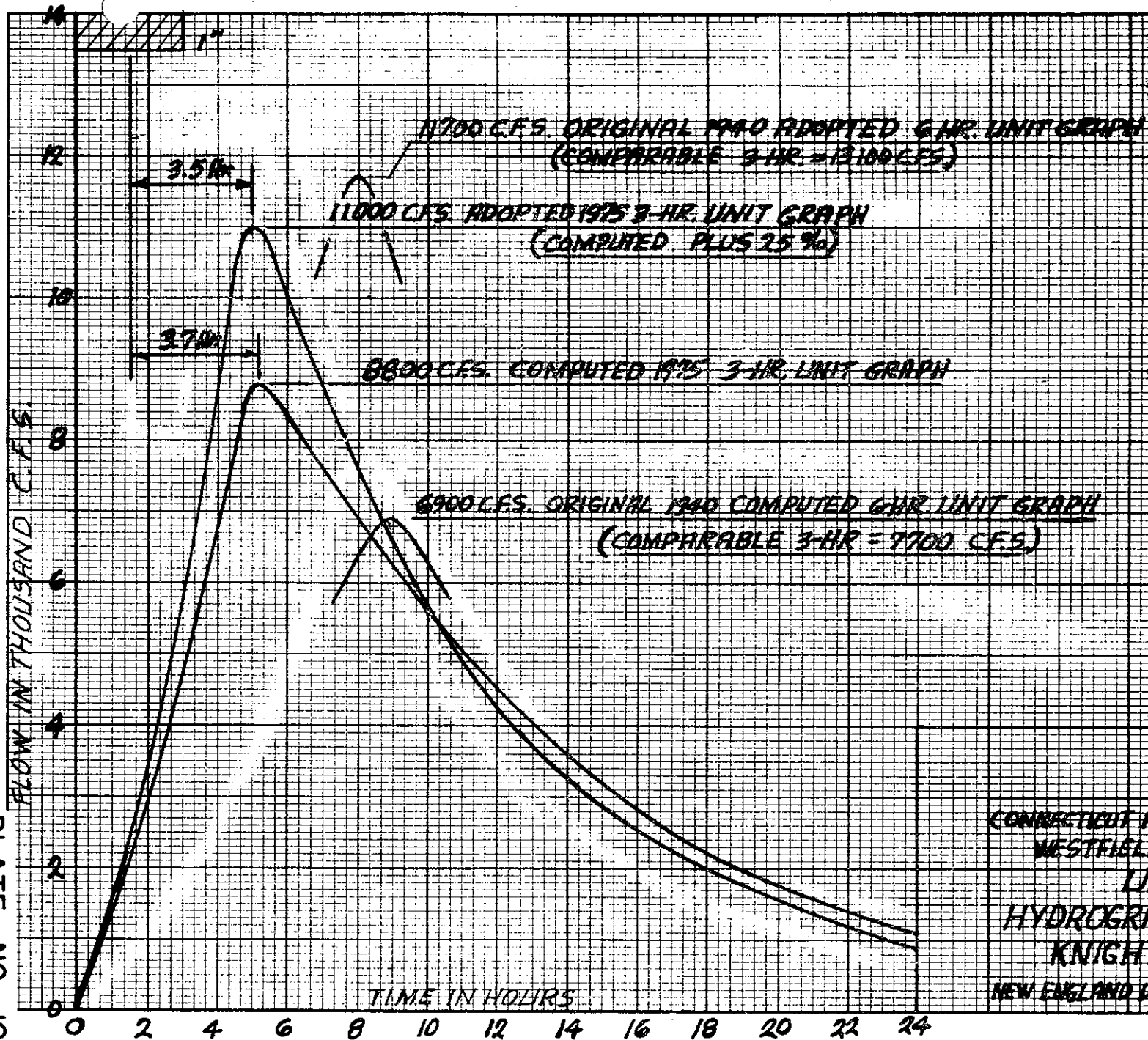
(17) Q_{DR} 8800 CFS. (18) Q_{DR} 53.7 CFS/50 MI. (19) Q_D 9400 CFS. (20) t_{DR} 3.4 HRS.

(21) t_p 3.3 HRS. (22) t_v 7.0 HRS. (23) C_{TR} 0.52 (24) C_p^{640} 182 W_{50} 9.9 HRS. W_{75} 5.2 HRS.

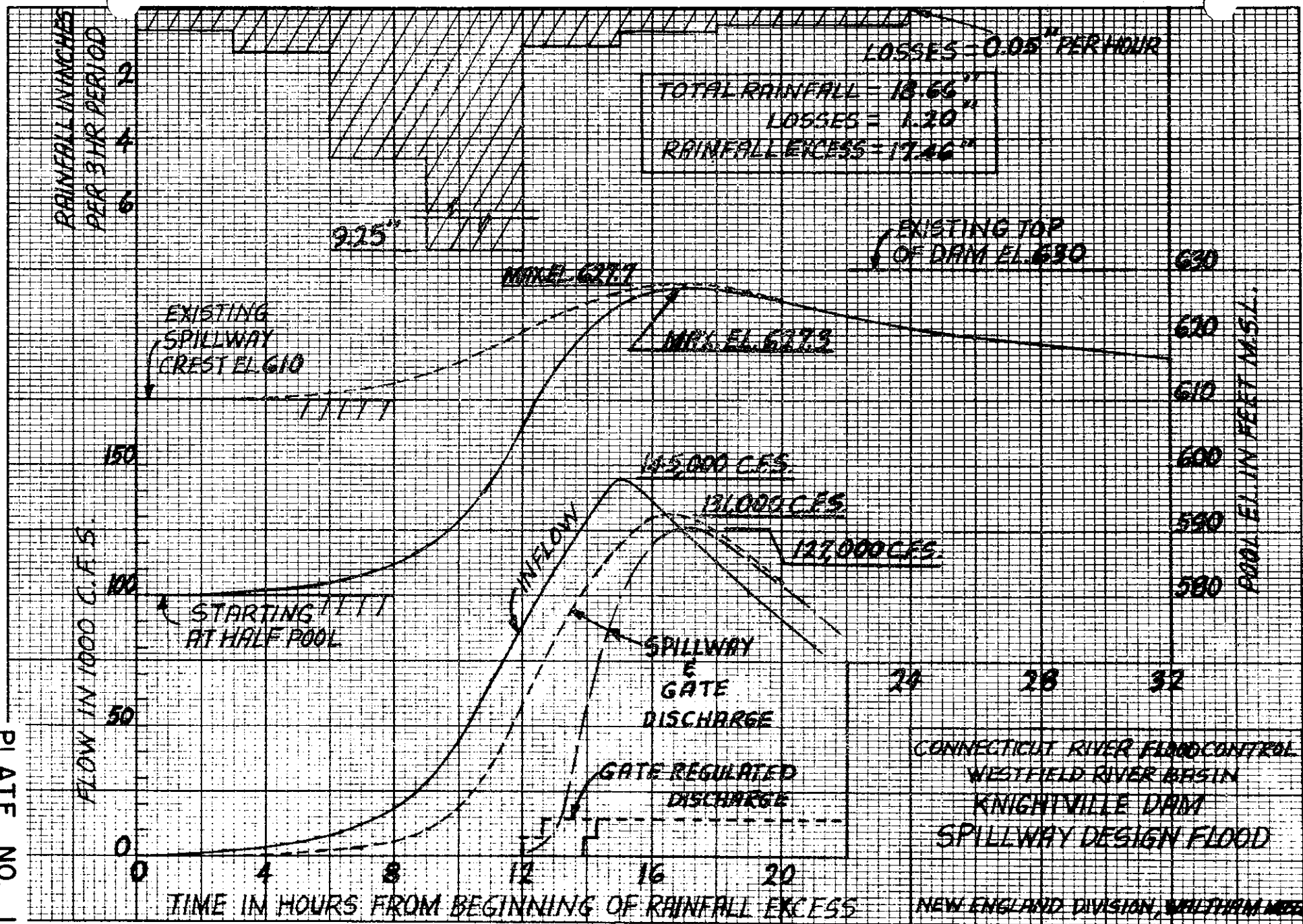
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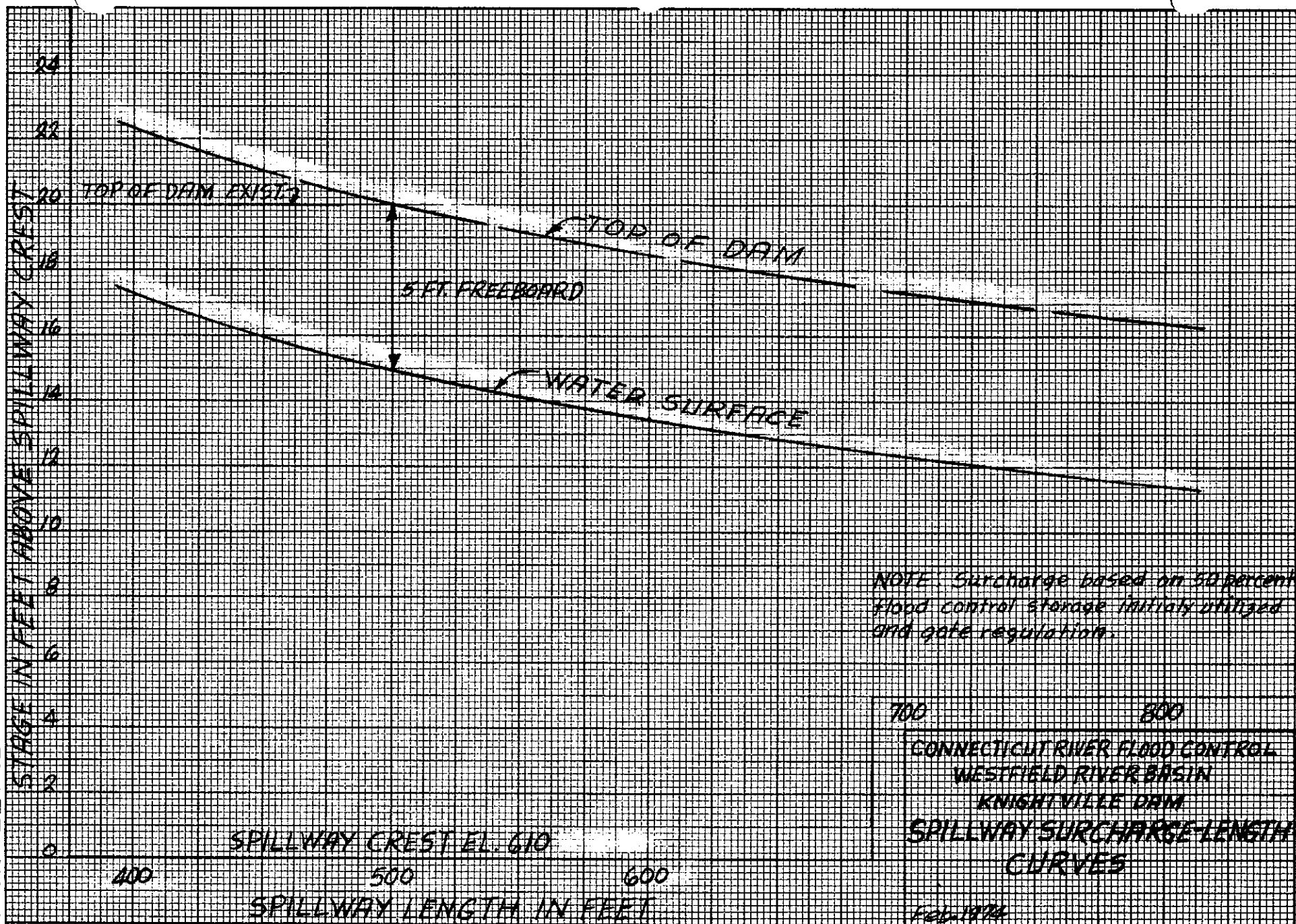
DATE _____

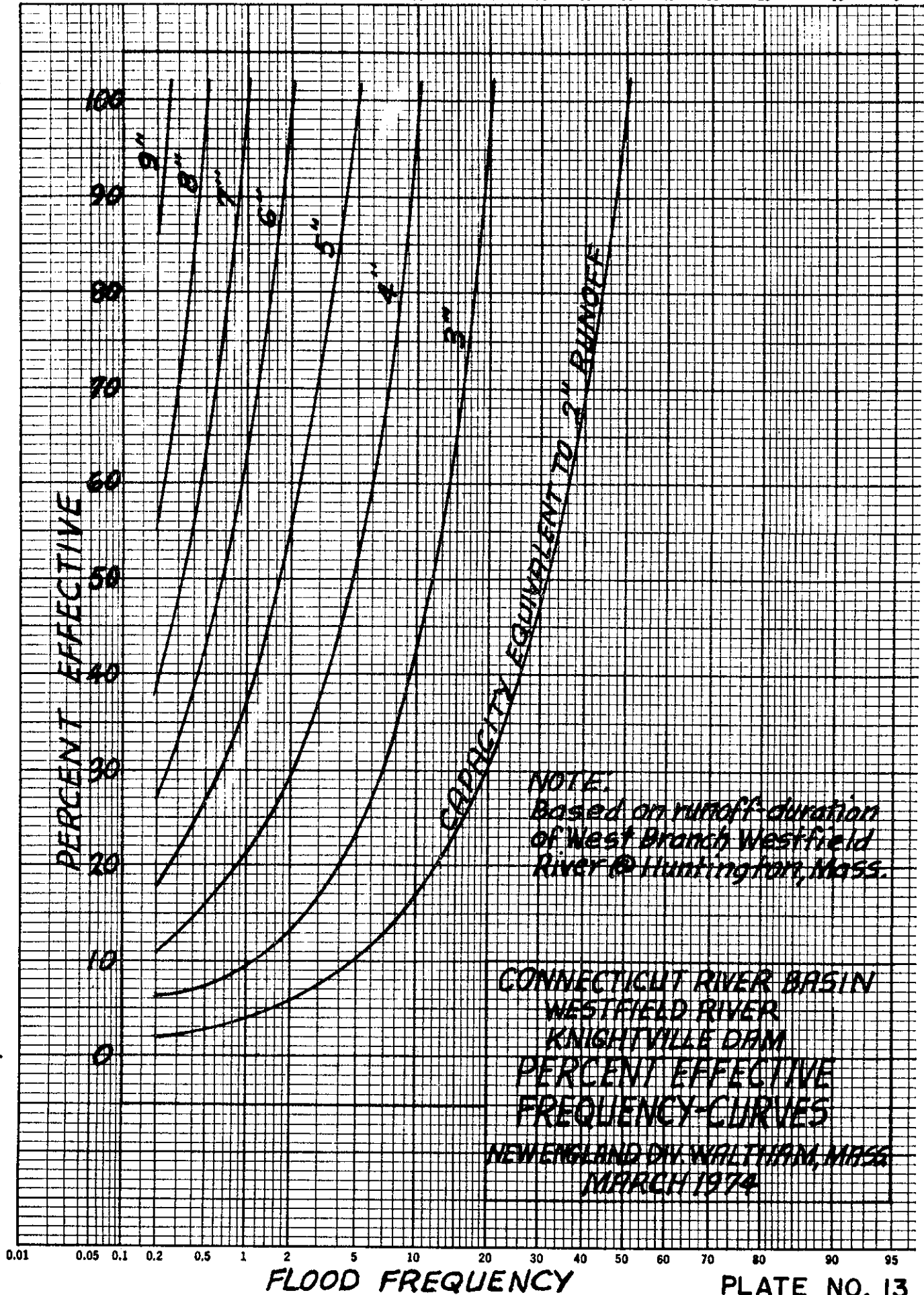
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CONNECTICUT RIVER FLOOD CONTROL
WESTFIELD RIVER BASIN
UNIT
HYDROGRAPH COMPARISON
KNIGHTVILLE DAM
NEW ENGLAND DIVISION, WASHINGTON, D.C.







**KNIGHTVILLE DAM
MODIFICATION
FEASIBILITY REPORT
FOR
WATER RESOURCES DEVELOPMENT**

**PERTINENT
CORRESPONDENCE**

**PREPARED BY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY**

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PERTINENT CORRESPONDENCE

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UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
New England Area Office
P. O. Box 1518
55 Pleasant Street
Concord, NH 03301

August 26, 1976

Division Engineer
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Sir:

Enclosed is the U.S. Fish and Wildlife Service's special report on modifications for the Knightville Dam and Reservoir, Westfield River Watershed, Huntington, Massachusetts. This report supersedes the Service's report on this project transmitted to you on 14 July 1976.

Sincerely yours,

John E. Harney
Acting Field Supervisor, NEAO

MAK/bmk:JEH

cc: RO, AEV
Arthur Neill, MA DIF&W
Win Seville, MA DIF&W



Appendix 2

KNIGHTVILLE DAM AND RESERVOIR,
WESTFIELD RIVER WATERSHED, HUNTINGTON, MASSACHUSETTS

Special report of the U.S. Fish and Wildlife Service on a plan being developed for increasing the flood storage capacity of the Knightville Reservoir by the New England Division, U.S. Army Corps of Engineers.

August 26, 1976

This study is being carried under the authority of a Resolution of the Committee on Public Works of the United States Senate, adopted 11 May 1962.

This special report of the Fish and Wildlife Service is submitted in fulfillment of provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), and has been coordinated with the Massachusetts Department of Inland Fisheries and Wildlife. The Service included analysis of the fish and wildlife impact of a recreation pool at the Knightville project in a report prepared for the Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, and published in 1970 (Appendix G).

Construction of the Knightville Dam was completed in 1941. It is an earth-fill type with a dumped rock covering. It rises 160 feet above the streambed. When filled to capacity, the reservoir has a flood storage capacity of approximately 49,000 acre feet, and inundates 960 acres. This full flood pool extends about 5 miles upstream from the dam. Under normal flow conditions, its three gates are kept open and the reservoir empty.

Project modification would consist of increasing the flood storage capacity by raising the height of the dam by 11 feet and the spillway crest 8.5 feet. The intake tower and appurtenant structures would also be modified to accommodate these changes.

The additional height will be gained by increasing the slope of the dam and spillway from approximately 1 foot in 3 feet to about 1 foot in 2½ feet. This increase will be tapered out about 30 feet above the base. With the proposed modifications, the flood pool would be increased to 1,025 acres. When filled to capacity, it would inundate approximately 0.3 miles of the East Branch of the Westfield River, more than the present maximum flood pool. An additional 45 acres will be acquired to accommodate the increased flood storage capacity of the reservoir.

No change is expected in the operation during a flood. The drawdown schedule will remain approximately the same, the exception being a rare flood of catastrophic magnitude. This project will remain single purpose, i.e., no recreation pool will be constructed. Any spoil material generated during construction will be deposited in Government-approved sites.

Appendix 2

The Knightville project area supports both stream fishery and wildlife resources. The portion of the East Branch of the Westfield River within the flood pool is seasonally stocked with trout to augment the existing coldwater fishery.

The open area within the flood pool is stocked with pheasants in the fall and provides one of the few hunting opportunities of this type in the watershed. In addition, this area provides small game and deer hunting opportunities.

The Service's analysis of the stream and pond fishery resources of the Connecticut River Basin during the Comprehensive Water and Related Land Resources Investigation initiated in 1962, demonstrated that by 1980 a demand exceeding the supply of coldwater stream fishery resources would have manifested itself in the lower basin. By 2020, this demand would have increased a hundredfold. If the latent demand were examined, the need for additional coldwater stream fishing opportunities would be considerably greater. Preservation and improvement of the existing stream resources in this portion of the Basin is, therefore, imperative.

During construction, the noise and increased traffic in this area will cause some disturbance to the fish and wildlife inhabitants of the project area. It will also deter stream fishing near the dam. This adverse impact is, however, expected to be minimal and of relatively short duration. Disposal of spoil material generated during construction of the proposed project could cause adverse impacts if used as fill for wetland areas. This impact can be avoided by placing the spoil in suitable upland sites.

Since the modified project's operation schedule will remain the same, long range habitat and fish and wildlife resource impacts will be only minimally greater than those already observed within the sphere of proposed project influence. They are not expected to be significant.

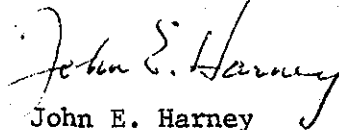
The addition of flood storage at the Knightville project could indirectly impact the fish and wildlife resources in the lower, more populated reaches of the Westfield River Basin. The psychological impact of increased flood level reduction in these reaches, could result in increased construction in the downstream floodplain, the loss of the wildlife habitat, and loss of access for anglers. This impact, as well as possible flood damage, can, however, be reduced by instituting floodplain zoning in these reaches.

Modification of this project could also encourage consideration of additional structural flood reduction in the Westfield and West Springfield areas. The impacts of such a project(s) will be evaluated separately.

The U.S. Fish and Wildlife Service has no objection to the modification of the Knightville Dam and Reservoir as presented in the 14 May 1976 Announcement of a public meeting on the proposed project.

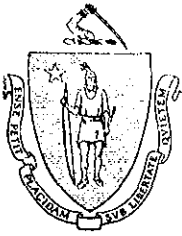
We recommend that: Any spoil material be disposed in xeric upland sites; this would include land fill areas.

Should additional changes be made, particularly if the construction of a recreation or water supply pool is contemplated, we would appreciate early notification.



John E. Harney
Acting Field Supervisor, NEAO

MAK/bmk:JEH



The Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Department of Environmental Management
Leeverett Saltonstall Building, Government Center
100 Cambridge Street, Boston 02202

EVAN S. DOBELLE
COMMISSIONER

November 22, 1976

Joseph L. Ignazio
Chief, Planning Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

I have consulted with the Division of Water Resources concerning the modification of Knightville Reservoir discussed in your letters of November 16, 1976. While this department agrees to the need of additional water-based recreational opportunities in the Westfield drainage, we agree that the inclusion of permanent water storage is not feasible at Knightville for both engineering and environmental reasons.

We are aware that the City of Westfield is one of the most seriously flood prone communities in the Commonwealth. The provision of additional flood storage is desirable, but not a complete solution. A combination of land use controls, flood proofing, local protection works and possibly relocation is needed in Westfield. Encouragement by both state and federal agencies will be required to implement this needed blend of flood management measures.

We wish to support some of the local concerns expressed at the hearing chaired by Colonel Boivin on June 15, 1976, in Huntington. In final project design, great care should be afforded to provisions which would minimize siltation, noise and other nuisance conditions created on and off the project site. Specific concerns regarding the routes, hours of use and sources to be used in bringing fill material to the site should be addressed.

Assuming that the benefit-cost relationships continue to be favorable, we support the completion of the feasibility study leading to the provision of additional flood storage at the Knightville Reservoir in Huntington, Massachusetts. This letter shall constitute a reply from the Division of Environmental Management and its member agency, the Division of Water Resources.

Sincerely yours,

A handwritten signature in black ink, appearing to read "Evan S. Dobelle". The signature is fluid and cursive, with the first name "Evan" being more prominent than the last name "Dobelle".

Evan S. Dobelle
Commissioner

ESD/ehc/gm



DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
JOHN F. KENNEDY FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203

November 23, 1976

REGION I

IN REPLY REFER TO:
1C

Mr. Joseph L. Ignazio
Chief, Planning Division
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

Subject: Knightville Dam and Reservoir

Maurice E. Frye, who is currently serving as the Regional Administrator for the Department of Housing and Urban Development, asked me to respond to your letter of November 16, 1976, which was addressed to Mr. James J. Barry, Mr. Frye's predecessor.

We appreciate the opportunity you have provided this office to comment on the proposed modification to the Knightville Dam.

Because of the nature of our responsibilities with respect to administering housing, community development and planning programs, we have no comments to offer in regard to the actions your agency proposes to take.

However, if you have not done so already, we suggest that you contact the Lower Pioneer Valley Regional Planning Commission in West Springfield, Massachusetts to solicit their comments. This agency is responsible for coordinating planning activities for the area included within Hampshire and Hampden Counties utilizing comprehensive planning assistance funds provided by HUD along with other local, state and federal financial resources.

Sincerely,

A handwritten signature in dark ink, reading "Frank V. Del Vecchio", is written over a horizontal line.

Frank V. Del Vecchio
Assistant Regional Administrator
for Community Planning and Development

Appendix 2

NEW ENGLAND REGIONAL COMMISSION

53 STATE STREET
BOSTON, MASSACHUSETTS 02109

November 29, 1976

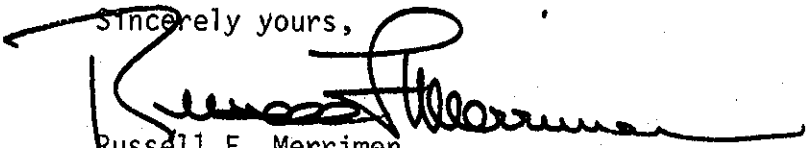
Mr. Joseph L. Ignazio, Chief
Planning Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

Thank you for your letter of November 16, 1976, requesting our comments regarding the feasibility study on modification of the existing Knightville Dam and Reservoir Project. We have reviewed your letter and attached material and have no substantive comment to make.

We wish you luck towards the successful completion of your Project.

Sincerely yours,



Russell F. Merrimen
Federal Cochairman

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
NORTHEASTERN AREA, STATE AND PRIVATE FORESTRY
6816 MARKET STREET, UPPER DARBY, PA. 19082
(215) 596-1671

8400

December 1, 1976



Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Refer to: NEDPL-P, Feasibility
Study, Knightville Dam and
Reservoir Project, MA

Dear Mr. Ignazio:

Without vegetation maps or descriptions of forest land above the proposed dam modification, it is difficult to estimate the effect of this project on forested land. If an environmental assessment or statement is prepared, we think it should include an estimate of losses of wildlife habitat and of other vegetation.

Thank you for the opportunity to review this Study.

Sincerely,

DALE O. VANDENBURG
Staff Director
Environmental Quality Evaluation



United States Department of the Interior

BUREAU OF OUTDOOR RECREATION

NORTHEAST REGIONAL OFFICE

Federal Building - Room 9310

600 ARCH STREET

Philadelphia, Pennsylvania 19106

IN REPLY REFER TO:

4120

December 1, 1976

Mr. J. L. Ignazio
Chief, Planning Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

This is in response to your letter of November 16, 1976 concerning modification of the Knightville Dam and Reservoir. We have no comments on the proposal.

Sincerely yours,

MICHAEL H. GORDON, Chief
Division of Water and
Environmental Planning



Appendix 2



TOWN OF HUNTINGTON

HUNTINGTON, MASSACHUSETTS

BOARD OF SELECTMEN

Hans Schott, Chairman
William C. Gaitenby
Robert A. Smith

December 2, 1976

Mr. Joseph L. Ignazio
Chief, Planning Division
NED, Corps of Eng.
424 Trapelo Road
Waltham, MA 02154

Re: NEDPL-P

Dear Mr. Ignazio,

The Board of Selectman of Huntington wish to be recorded as in favor of the proposed changes at Knightville Dam to further reduce flood losses in the lower Westfield River Valley.

Very truly yours,

For the Board of Selectmen,

William C. Gaitenby
William C. Gaitenby,
2nd Member

WCG/cw

Appendix 2

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

29 Cottage Street, Amherst, Massachusetts 01002

December 2, 1976

Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

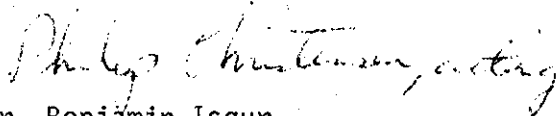
Attention of: NEDPL-P

Dear Mr. Ignazio:

We have reviewed the material you sent us on the proposed modifications to Knightville Dam and Reservoir, and we have no comments to offer at this time.

Thank you for providing us the opportunity to review this proposal.

Sincerely,



Dr. Benjamin Isgur
State Conservationist





DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGION I
JOHN F. KENNEDY FEDERAL BUILDING
GOVERNMENT CENTER
BOSTON, MASSACHUSETTS 02203

OFFICE OF
THE REGIONAL DIRECTOR

Mr. Joseph L. Ignazio, Chief, Planning Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02154

Dear Mr. Ignazio:

Re: Your Reference NEDPL-P

Reference is made to your letter of November 16, 1976, as indicated above.

Based on a review of the correspondence and a telephone call to your project engineer, Mr. Civiello, it is our understanding that:

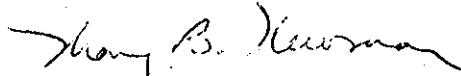
- a. There are no buildings in the new full flood reservoir;
- b. All roads within the area have been abandoned;
- c. Pheasant hunting is permitted in the reservoir area;
- d. Corps of Engineers Personnel use abandoned roads to make investigations and surveys;
- e. There are no Historical Sites in the area;
- f. Generation of electric power was considered and found not feasible;
- g. Camping is permitted at Indian Hollow camping area in the upper reach of the reservoir.
- h. Failure to accomplish this project could have an unfavorable effect on the general welfare of communities located downstream of the Knightville Dam by allowing the present potential flood condition to continue; and

- 2 -

- i. Some unfavorable environmental impact appears to be inevitable during the construction phase. However, effective landscaping and restoration work should restrict this to a temporary period only. The overall effect should be favorable.

From this brief analysis, it appears that the interests of this Department are being considered in your feasibility study of the subject project. We, therefore, concur with the intent of your study and have no adverse comments.

Sincerely yours,



Mary B. Newman
Regional Director



DIRECTOR

The Commonwealth of Massachusetts
Division of Fisheries and Wildlife
Leverett Saltonstall Building, Government Center
100 Cambridge Street, Boston 02202

December 8, 1976

Mr. Joseph L. Ignazio, Chief
Planning Division
Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02154

Re: DEDPL-P

Dear Mr. Ignazio:

Your letter of 16 November 1976 and the accompanying maps relating to the modification of the existing Knightville Dam and reservoirs have been received and reviewed by this Division.

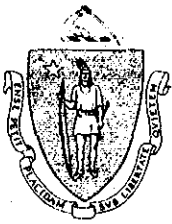
No official objection is raised to the physical aspects of the project as presented but I do have great personal reservation concerning the cost effectiveness of this modification as compared with the needs projected in the late thirties when the project was originally constructed.

Very truly yours

A handwritten signature in cursive script, reading "Matthew B. Connolly, Jr.".

Matthew B. Connolly, Jr.
Director

MBC/cms



~~STATE OF MASSACHUSETTS~~

DIVISION OF WATER
POLLUTION CONTROL

The Commonwealth of Massachusetts

Water Resources Commission

Leverett Saltonstall Building, Government Center

100 Cambridge Street, Boston 02202

Water Quality and Research Section
P. O. Box 545
Westborough, Massachusetts 01581

December 8, 1976

Mr. Joseph Ignazio, Chief
Planning Division
New England Division,
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

Thank you for affording this Office the opportunity to review the proposed modifications to the Knightville Dam.

This Office is not opposed to this project as long as water is stored only during periods of high flow. Several reaches of the Westfield River develop serious dissolved oxygen deficiencies during low flow periods. If water were retained during these periods, the problem would be aggravated.

Therefore, this Office has no objections to this proposed plan as long as it does not adversely affect the existing low flow conditions in the Westfield River.

Sincerely,

Alan Cooperman

Alan Cooperman
Associate Sanitary Engineer

AC/rg

Appendix



United States Department of the Interior

OFFICE OF THE SECRETARY
NORTHEAST REGION
JOHN F. KENNEDY FEDERAL BUILDING
ROOM 2003 M & N
BOSTON, MASSACHUSETTS 02203

December 17, 1976

Mr. Joseph L. Ignazio
Chief, Planning Division
Corps of Engineers
New England Division
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Ignazio:

Thank you, by your letter of November 10, for the opportunity to review the proposal to modify the existing Knightville Dam and Reservoir project.

Our only comment is to recommend that prior to completion of the feasibility study a qualified archeologist such as Dr. Dena Dincauze (Department of Anthropology, University of Massachusetts, Amherst, Massachusetts 02703) be contacted for initial outlooks on the probability of archeological values to be affected by the project. Also, prior to final commitment to the selection of a specific modification alternative, the Corps should check with the State Historic Preservation Officer to assure itself of no conflict with historic sites being nominated to the National Register of Historic Places.

Additionally, I understand that the Northeastern Region Office of the Bureau of Outdoor Recreation supplied their comments on this project directly to you.

Sincerely yours,

ra Roger Sumner Babb
Special Assistant to
the Secretary



Appendix 2
17

LOWER PIONEER VALLEY
REGIONAL PLANNING COMMISSION

26 Central St., West Springfield, Massachusetts 01089, Tel. 413-739-5383

K. M. MUNNICH
Planning Director

December 21, 1976

Mr. Joseph Ignazio, Chief
Planning Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Re: Knightville Dam and Reservoir Project

Attention: NEDPL-P

Dear Mr. Ignazio:

We are in receipt of your letter of December 1, 1976 requesting our comments on possible modifications to the existing Knightville Dam. It is our understanding that this proposal is the product of a feasibility study, which has yet to be completed, but which does now indicate that the provision of additional flood control storage at the Knightville Dam is both feasible and warranted. This extra storage capacity would be achieved by raising the Knightville Dam and spillway; this would further reduce flood losses in the lower Westfield River Valley.

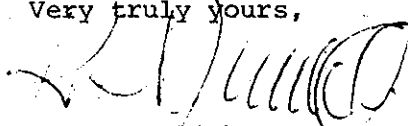
It is somewhat difficult to assess in a comprehensive manner this proposal, its benefits, and its impact, without reviewing the feasibility study itself and supporting data. Assuming that the project is the most feasible and appropriate alternative, it would appear that the project does indeed afford additional downstream flood protection with minimal environmental impact. The latter can be achieved through the use of environmentally sensitive construction techniques and satisfactory resolution of a potential encroachment of the full flood control pool on non-federal flood control land in Chesterfield. (The land in question appears to be state forest land from our interpretation of Plate 2 relative to our own land use data base.)

While we appreciate receiving advance notice of this project, we feel that valid and constructive comments cannot be made on it until we receive the study itself. This would afford our staff, Environmental Advisory Committee, and Commissioners the opportunity to review it in detail. We are particularly interested in the analysis of all alternatives initially considered and the project's relationship to the 1980 Connecticut River Basin Plan. We would also like to see how the configuration of the proposed full flood control pool compares to the one that would result from the existing dam.

Mr. Joseph Ignazio, Chief
December 21, 1976
Page 2

Timely receipt of the aforementioned material would assist us greatly in completing our review. Should there be any problems in supplying us with this information, I would appreciate your notifying me. Thank you for your anticipated assistance.

Very truly yours,



K. M. Munnich
Planning Director

KMM/BAK:fe

cc: Kenneth H. Barrows, LPVRPC, Huntington
John A. Bisbee, LPVRPC, Chesterfield
Hans Schott, Ch., Board of Selectmen, Huntington
Charles Bisbee, Jr., Ch., Board of Selectmen, Chesterfield
Elinor Hartshorn, Ch., Environmental Advisory Committee



The Commonwealth of Massachusetts

EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL QUALITY ENGR.
DIVISION OF WATERWAYS

100 Nashua Street, Boston 02114

December 28, 1976

Joseph L. Ignazio, Chief
Army Corps of Engineers, Planning Division
424 Trapelo Road
Waltham, Mass. 02154

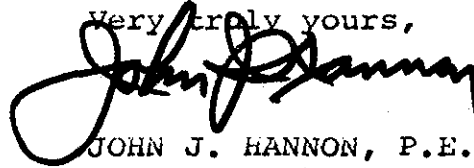
Re: NEDPL-P
Dam #1-8-143-3
Knightville Dam
Huntington

Dear Mr. Ignazio:

Your November 16, 1976 letter to D.P.W. Commissioner Carroll has been referred to me for reply. In the future, please direct correspondence concerning Massachusetts dams to Commissioner David Standley, Department of Environmental Quality Engineering, 100 Cambridge Street, Boston, Mass. Chapter 706 of the Acts of 1975 amended Chapter 253, Sections 44 et. seq. (Dams Safety Act) and placed jurisdiction with Commissioner Standley.

I concur with the Corps proposal to provide additional flood control storage by raising the elevation of the Knightville Dam. If I may be of assistance in the implementation of the project, please contact me.

Very truly yours,


JOHN J. HANNON, P.E.
CHIEF ENGINEER

EJM:eh

cc: John J. Carroll
Dean Amidon
Robert Jordan

NEW ENGLAND RIVER BASINS COMMISSION

NERBC

55 COURT STREET • BOSTON, MASSACHUSETTS 02108
PHONE (617) 223-6244

January 19, 1977

Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

This will reply to your letter of November 16 requesting comments on the Corps' feasibility study concerning modification of the existing Knightville Dam and Reservoir project on the Westfield River in the Connecticut River Basin. Your letter notes that the Corps considered modifying the project to provide storage for a recreational pool, low flow augmentation, and additional flood control, but that only additional flood control storage to further reduce flood losses in the lower Westfield River valley is warranted.

In its findings and recommendations on the 1970 Connecticut River Comprehensive Investigation (the NERBC 1980 Connecticut River Basin Plan), NERBC endorsed the Coordinating Committee's recommendation for modification of the dry bed Knightville project to include a permanent pool for recreation and low flow augmentation for fishery enhancement, with two qualifications: 1) subject to satisfactory completion of environmental impact evaluations pursuant to the National Environmental Policy Act, as defined in the introduction to NERBC's findings and recommendations on the 1980 Early Action Plan; 2) subject to NERBC's investigation of the replacement of wildlife habitat that would be lost by creation of a recreational pool (pages 73, 74, 95, 96).

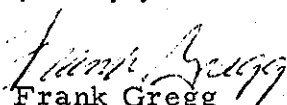
These environmental qualifications haven't come into play because of the Corps' conclusion that a permanent pool isn't economically justified and therefore this recommendation should be dropped. The Coordinating Committee and NERBC 1980 Plan didn't consider project modifications for additional flood control. Therefore, I should simply point out that the Corps' feasibility study in effect updates the 1980 Plan by deleting the permanent pool recommendation and substituting a recommendation that the dry bed flood storage capacity at Knightville be enlarged.

Appendix 2

The desirability of increased reservoir storage above the City of Westfield wasn't considered in NERBC's Level B Connecticut River Supplemental Flood Management Study. However, the final report approved by NERBC December 15 makes frequent reference to Westfield's very serious flood damage potential and to structural and non-structural measures urgently needed to alleviate the problem (pages 161, 162, 180, 206-212). The final report specifically endorses the City's decision to proceed with detailed feasibility studies of a local protection project proposed by the Corps (pages 161, 162), although final approval would necessarily hinge on the outcome of detailed studies.

Unless Massachusetts or other NERBC federal members take a different view, I would therefore think it could be inferred that NERBC also encourages further consideration of the Knightville Reservoir modification as outlined in your letter. However, this wasn't brought before the NERBC Connecticut River Coordinating Group prior to final Commission action on The River's Reach, and therefore it's not feasible at this time to incorporate a positive statement to this effect in the final report.

Very truly yours,


R. Frank Gregg
Chairman

RFG:ht

cc: David Harrison
Evelyn F. Murphy, Mass. OEA
Charles Kennedy, Mass. WRC
Robert Ryder, Dept. of the Interior
Walter Newman, EPA



MAYOR'S OFFICE

59 COURT STREET, WESTFIELD, MASSACHUSETTS 01085 413 568-0316 413 568-5543

May 2, 1977

JOHN J. RHODES
MAYOR

John P. Chandler, Colonel,
Corps of Engineers
Division Engineer
U. S. Corp of Engineers
New England Division
224 Trapelo Road
Waltham, Mass. 02154

Dear Colonel Chandler:

I wish to inform you and the United States that the City of Westfield, Massachusetts offers its enthusiasm and willingness to contribute the financial assistance necessary for the completion of the proposed flood protection dike system intended to insure the safety of the lives and properties of its citizens. The City additionally agrees to the following assurances of local co-operation and participation prior to actual construction and will:

1. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction and maintenance of the project.
2. Hold and save the United States free from damages due to construction works except damages due to the fault or negligence of the United States or its contractors.
3. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army.
4. Provide without cost to the United States all alterations and replacements of existing utilities.
5. Prescribe and enforce regulations to prevent encroachment on both the improved and unimproved channels, and manage all project related functions.
6. Comply with the provisions under Sections 210 and 305 of Public Law 91-646, 91st Congress, approved January 2, 1971, entitled "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970"

After considering the alternative non structural proposals regarding flood protection, the past, present and likely future patterns of development within the flood prone areas, and the historic incidences of flooding within the City, I have determined that the proposed dike

Appendix 2

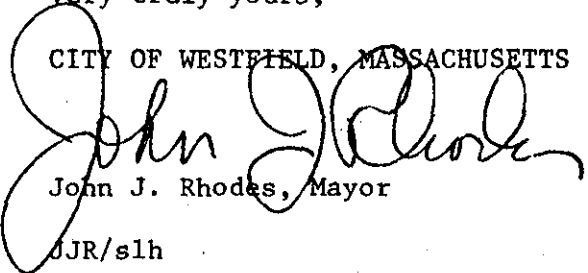
May 2, 1977

system remains the only practical solution for the future safety and welfare of Westfield's citizens.

I remain confident that the Congressional authorities will act favorably regarding the Federal participation essential for this proposal and consequentially to great benefit for the people of Westfield.

Very truly yours,

CITY OF WESTFIELD, MASSACHUSETTS



John J. Rhodes, Mayor

JJR/slh

**KNIGHTVILLE DAM
MODIFICATION
FEASIBILITY REPORT
FOR
WATER RESOURCES DEVELOPMENT**

**STABILITY ANALYSIS
OF STRUCTURES
AT KNIGHTVILLE DAM**

**PREPARED BY
FAY, SPOFFORD AND THORNDIKE, INC.
BOSTON, MASSACHUSETTS
FOR
THE NEW ENGLAND DIVISION
CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY**

**A
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3**

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS

STABILITY ANALYSIS OF STRUCTURES

KNIGHTVILLE DAM

HUNTINGTON, MASSACHUSETTS

REPORT

CONTRACT NO. DACW33-74-C-0065
Line Item 1

Fay, Spofford & Thorndike, Inc.
Engineers
Boston, Massachusetts

July, 1974

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PART I

GENERAL

I - Section 1 - Project Criteria.

List of recent and updated stability criteria and instructions provided by the Corps of Engineers, New England Division:

Engineering Manuals:

- EM 1110-2-2101 - Working Stresses for Structural Design (17 Jan. 1972).
- EM 1110-2-2200 - Gravity Dam Design (25 Sept. 1958).
- EM 1110-2-2400 - Structural Design of Spillways and Outlet Works (2 Nov. 1964).
- EM 1110-2-2501 - Wall Design: Flood Walls (18 June 1962).
- EM 1110-2-2502 - Retaining Walls (25 Jan. 1965).

Engineer Technical Letters:

- ETL 1110-2-184 - Gravity Dam Design (25 Feb. 1974).
- ETL 1110-2-109 - Structural Design for Earthquakes (21 Oct. 1970).

Pertinent Hydraulic Data:

Hydrologic Data for Structural Stability -
Analysis of Spillways

List of design computations and drawings:

- (1) Analysis of Design - 1939.
- (2) Analysis of Design - 1939: Appendix A.
- (3) Plans for Construction of Dams & Appurtenant Structures.

I - Section 2 - Description of the Dam and Operating Condition.

Knightville Dam is located on the Westfield River about 4 miles north of the town of Huntington, Massachusetts. Construction of the dam and other structures was initiated in 1939 and completed in 1941. Recreational facilities were provided. The dam is of the hydraulic earth-fill type with a dumped rock shell. It has a top length of 1,200 feet and a maximum height above the stream bed of 160 feet. A curved concrete spillway, about 405 feet long, is located

on rock in a natural saddle at the west end of the dam. The crest of the spillway is at Elevation 610; this is 20 feet below the top of dam to insure the dam against overtopping during the maximum probable flood. Gated outlet works, founded on bedrock, are located under and at the west end of the dam embankment. The three gates are normally kept open and the reservoir empty. During time of flood, the gates are closed to temporarily store floodwaters in the reservoir.

The spillway was designed to have sufficient capacity to pass the spillway design flood, which is 50 percent greater than the maximum predicted flood. The outlet structure has a discharge capacity of 8,500 cfs. It was designed to empty a full reservoir (water at Elevation 610) within a period of a few days. This has occurred only once since the dam was built. Normally, with the outlet gates just partially open, the water level in the reservoir does not reach the bottom of the spillway wall.

The hydrological data for structural stability, updated and furnished by the Contracting Officer, are as follows:

- (a) Full Pool Condition (pool at spillway crest, minimum tail water):

Energy gradient at spillway (ft. msl)	610.0
Tail-water energy gradient	463.0

- (b) Design Discharge Condition (reservoir at peak level of probable maximum flood and corresponding tail waters):

Energy gradient at spillway	629.3
Tail-water energy gradient	510.0
Tail-water water surface	507.0

I - Section 3 - Criteria for Analysis.

The principal concrete structures and project features analyzed for stability consist of the following:

- (a) Intake Tower
- (b) Service Bridge Piers
- (c) Spillway
- (d) Spillway Retaining Walls
- (e) Concrete Toe Wall

Two members of our engineering staff visited the site on December 28, 1973 (copy of memorandum enclosed).

To check sliding resistance of structures under lateral loading, a method different from the original design calculations has been used. This is the Shear-Friction Factor of Safety formula, as outlined in the Engineer Technical Letter No. 1110-2-184 of 25 Feb. 1974. The sliding resistance is a function of the angle of internal friction and the unit shearing strength of the foundation material. Where the base of the concrete structure is embedded in rock, the passive resistance of the downstream layer of rock may be utilized in addition to the sliding resistance.

In the analysis of the Knightville Dam structures, the shear-friction safety factor formula used includes all three contributing resistances, namely, the friction, the shearing strength, and the passive reaction where applicable. All the structures were analyzed for stability at the interface between rock and the concrete and bond shear value as shown in Section I-4 was used instead of a higher shearing strength of the rock.

For the spillway weir and the toe wall, a minimum shear-friction factor of safety of 4 is required for all conditions of loading when earthquake is not considered. When earthquake is considered, this factor of safety should exceed 2-2/3. Retaining walls on earth require a shear-friction factor of safety of $\tan \phi / 1.5$.

The resistance to overturning is determined according to current criteria by the location of the resultant of vertical forces at the base. With active earth pressures and without seismic forces, the resultant must be located within the kern. Where earthquake is considered, it is acceptable if the resultant stays within the width of the base. The kern is the middle third of the base width.

The original design of 1939 did not consider earthquake pressures because the possibility of an earthquake occurring at the time of flood was considered to be extremely remote. This analysis includes seismic forces, as specified for Zone 2 (moderate damage), with acceleration of 0.10g. Because the Knightville Dam is located on the border line between Zone 1 and Zone 2, as shown on the Seismic Risk Map of the U.S., included with ETL 1110-2-109, it is considered appropriate and more conservative to use Zone 2 requirements.

The seismic forces applied to this stability analysis are in accordance with EM 1110-2-2200 of 25 Sept. 1958:

- (a) Inertia force $P_{e1} = 0.10W$, acting horizontally through the center of gravity in any direction.
- (b) Dynamic water by Westergaard's formula, first published in 1933, and expressed in terms of horizontal force P_{e2} and moment M_e at any depth y . Factor $C = 51 \text{ lbs./ft.}^3$ was used throughout assuming $t = 1 \text{ sec.}$ This factor does not change appreciably within the range of height from 30 feet to 200 feet.
- (c) Dynamic earth pressure in accordance with EM 1110-2-2502 of 25 Jan. 1965, was applied at about $2/3$ of the fill height. This pressure is equal to about 20 percent of static lateral earth pressure. The backfill between a sloping wall and a vertical plane through the heel was added to the wall mass for calculation of inertia force P_{e1} .

Ice pressure, used where applicable, is $5,000 \text{ psf} \times 2 \text{ feet} = 10,000 \text{ pounds per linear foot of structure}$ (ref. to EM 1110-2-2200, Sec. 2-07). In the original design of 1939, ice force applied was 1,000 pounds per linear foot only (App. A, p. 70).

The uplift pressure at any point under all structures is the tail-water pressure plus the pressure measured as an ordinate from tail water to the hydraulic gradient between the upstream and the downstream sides. The uplift considered in the original design of 1939 was only 50 percent of these values. In this analysis, the uplift pressure is considered to act over 100 percent of the base area, measured from the upstream to the downstream edge.

I - Section 4 - Evaluation of Foundations on Rock.

Reference is made to "Analysis of Design," Corps of Engineers, Providence, Rhode Island, 1939.

Subsurface exploration for the existing dam was obtained by either core borings or test pits. Rock samples were obtained from cores, penetrating on the average of 13.5 feet below rock surface. Test pits were located in order to ascertain the character of the overburden in more detail than it was possible to do with borings. Site inspection

on subsurface exploration indicates that these rocks are on a part of extensive metamorphic formations, consisting of quartzitic schist and mica schist. The bedding is steeply inclined with angles of inclination varying between 60° west and 80° west. The strike of the bedding is approximately north-south.

Mechanical weathering, chiefly frost action, has affected the upper portions of the formation near the surface by opening small cracks along the bedding planes. In the quartzitic schist varieties, these cracks become less prominent or entirely disappear within varying depths of from 5 to 15 feet. In all other respects, the rock is structurally sound.

All concrete structures analyzed are shown on the plans to be founded upon solid rock. Excavation to sound rock was estimated to be approximately 4 feet deep in the spillway area. Sealing cracks and small fissures in the rock beneath retaining walls and the concrete weir were required during construction.

Allowable bearing pressure for the massive crystalline, igneous and metamorphic rock with minor cracks may be as high as 80 tons per square foot. Foliated, metamorphic rock, such as schist, may be loaded up to 35 tons per square foot. For the rock type as described in the Analysis of Design, 1939, an allowable unit shearing stress of 75 psi or more is permissible.

I - Section 5 - Allowable Unit Stresses at Interface of Concrete and Rock.

Allowable stresses at the bonded surface between concrete and rock are related to shear strength of 3,000 psi concrete and to the type of rock at the site. EM 1110-1-2101 refers to the ACI Building Code for allowable stresses in concrete with certain modifications. The following allowable stresses are used in this report:

- (a) Concrete - Compressive strength f_c' = 3,000 psi at 28 days.
- (b) Rock (weathered or unweathered schistose gneiss, ETL 1110-2-184, 25 Feb. 1974) -
Average compressive strength = 13,450 psi
Average shear strength = 1,800 psi.

- (c) Allowable bearing on rock - 35 tons/s.f. = 485 psi (less than allowable compression, direct or flexural, in concrete).
- (d) Shear at interface between rock and concrete = 75 psi. This value is lower than the allowable value based on shear strength of the rock or the allowable shear in unreinforced concrete footing.
- (e) Coefficient of frictional resistance = 0.7 (based on tangent of the angle of internal friction for foundation material or angle of sliding friction).

These allowable unit stresses may be increased by 33-1/3 percent with Group II Loadings, such as wind, ice or earthquake (EM 1110-2-2101).

PART II

RESULTS OF THE ANALYSIS

II - Section 1 - Intake Tower.

The intake tower is located at the upstream end of the tunnel directly above the transition section and is founded on solid rock. In plan, the tower measures approximately 35 feet by 46 feet at the top and has variable dimensions within its height, including diagonal counterforts, extending up the tower, at the four corners. The total height of the tower from the roof of the transition section to the floor of the operating house is 138 feet. The downstream wall of the tower rests against rock for a height of approximately 67 feet, leaving a free height of the tower of approximately 71 feet.

The tower was analyzed for stability at three levels; Elevations 545, 526.5, and 477 (on rock). Loading cases applied are those listed in EM 1110-2-2400, Section 3-07.c, entitled "Stability of Gate Structure at Upstream End." Applicable were Cases I through V, and IA, IIA, IIIA, and IVA, including seismic acceleration of 0.10g for Zone 2. During the analysis, obviously noncritical loading cases were eliminated by comparison with other loadings. A total of 18 loading cases for the three plan sections have been analyzed. Ten of the cases were considered at the base, Elevation 477. With combinations of lateral loads, both the axis of the weaker moment of inertia and the diagonal axis were considered.

At the upper levels, Elevations 545 and 526.5, the bending and shearing stresses in concrete are well within allowable limits. The stability requirements against overturning are satisfied as the resultant falls within the middle third of the base in all cases, I to V, except for Case II.

For Loading Case II with maximum ice pressure on one side, the resultant falls out of the kern with 78 percent of the base remaining in bearing. Considering the tower base embedment into the rock below Elevation 545.0 and the bearing of the diagonal counterforts against the rock providing additional overturning resistance, the resultant will be within the kern. With seismic loading, the resultant falls outside of the kern but well within the base. These are Cases IA, IIA, IIIA, and IVA.

At the base level, Elevation 477.0, with seismic loading, the minimum sliding factor of safety based on frictional resistance only is 1.53. For all loading cases, the sliding stability criteria are satisfied. The bearing pressure on rock does not exceed 31.3 tons per square foot with seismic loading (vs. allowable $1.33 \times 35 = 46\text{T/S.F.}$) and is a maximum of 10.6T/S.F. for other loading cases.

Under the specified loading cases, the intake tower is stable and no modification or strengthening is required.

II - Section 2 - Service Bridge Piers.

Two intermediate piers of reinforced concrete founded on rock support the service bridge connecting the intake tower with the dam. The service bridge consists of three steel plate girder spans of 70 feet each. The design loading is AASHO H-15.

Loading cases considered are those specified for gravity dams in EM 1110-2-2200. The free standing Pier No. 1 was analyzed. Pier No. 2, built integrally with a retaining wall, is more stable and therefore, did not require a separate analysis.

Stability was checked at Elevation 558, which is the average depth of concrete foundation embedded in a sloping rock surface, as shown on design drawings. The top of pier is approximately 65 feet above this reference line. In calculating uplift forces for flood conditions, the bridge deck was assumed to be fully submerged as the roadway elevation is only a little more than one foot higher than the probable maximum flood. Factor of safety against uplift during flood is 2.2.

Wind loading of 30 psf was applied at 30° to the longitudinal axis of the bridge to give the maximum lateral load to be resisted by the minimum pier cross section. Ice forces, acting all around the pier, would not affect the stability of the pier.

The minimum factor of safety against sliding based only on frictional resistance is 3.0, greater than the required

factor of safety of 1.5. Maximum bearing pressure on rock is 15.9T/S.F. with earthquake loading, and only 5.2T/S.F. with wind loads.

For Pier 1, the resultant is within the kern of the base for Loading Cases I to IV, dead load plus wind. For Loading Case VI with uplift on the pier and earthquake forces, the resultant falls outside of the base. To prevent overturning of the pier, a horizontal reaction at the bridge deck through bearings on the pier is necessary. The reaction computed is relatively small, only 840 pounds. This force would have to be shared by at least two fixed bearings with eight 1-1/4" \emptyset anchor bolts, and transmitted to the entire bridge structure through the deck. It is unlikely that any horizontal movement of the top of the pier would occur and it would be limited to a 2-inch gap between the concrete deck curbing. Therefore, no remedial measures are needed to improve the stability of the service bridge piers.

II - Section 3 - Spillway.

The spillway is of a gravity wall type with an overflow spillway wier approximately 400 feet long at the crest. The structure is divided into fourteen concrete monoliths, typically 30 feet long and separated by expansion joints with copper waterstops. The central part consists of eight monoliths, varying in height from approximately 40 to 70 feet. The spillway crest is at Elevation 610. The toes of these monoliths are embedded in rock to a depth of at least 6 feet along the downstream side.

The three monoliths at the east end of the spillway were built to the initial crest elevation of 600 and later raised to the final elevation of 610. The total height is about 35 feet, the embedment of toe in rock is a minimum of 4 feet. The horizontal construction joint at Elevation 600 is reinforced with vertical steel dowels along the upstream face and with inclined dowels on the downstream side. The last monolith at the east end of the spillway is anchored into the retaining wall by means of horizontal steel dowels.

The four small monoliths at the west end of the spillway were initially built to Elevation 600 and then raised to

Elevation 610. These monoliths are only 16 feet high, with embedment of toe in rock to a minimum of 3 feet. There are five rows of steel anchors drilled into rock and dowels at both faces in the horizontal construction joint at Elevation 600. There is no indication of horizontal dowels into rock at the first monolith.

The width of the spillway wall approximately equals its height. As the monoliths are not connected by shear keys, each of them has to be stable by itself under any loading condition. Four monoliths were analyzed.

Loading cases applied are in accordance with EM 1110-2-2200, Section 3-01. Applicable were cases: II - normal operating; IV - flood discharge; and VI - normal operating with earthquake.

The hydrologic data supplied to us for this spillway are the following:

Loading Case II - Full Pool Condition (pool at spillway crest, minimum tail water):

Energy gradient at spillway (ft. msl)	610.0
Tail-water energy gradient	463.0

Loading Case IV - Design Discharge Condition (reservoir at peak level of probable maximum flood):

Energy gradient at spillway (ft. msl)	629.3
Tail-water energy gradient (ft. msl)	510.0
Tail-water water surface (ft. msl)	507.0

The critical values of the factors of safety against sliding, bearing pressures and location of resultant for each monolith analyzed are shown in Table 1.

For Sections A/24, B/24, and E/26, as shown on the original drawings, under Loading Case II including ice forces, the resultant remains within the middle third of the base; and under Loading Case VI, with earthquake forces, the resultant is always within the base. The overturning stability criteria is not satisfied for B/24 and E/26 sections under Loading Case IV - Flood Discharge. Spillway Section E/26 above the construction joint at Elevation 600 was analyzed for Loading Cases IV and VI and was found to be stable. To satisfy the overturning stability criteria, remedial measures are recommended for approximately the 315-foot length of the spillway weir where no anchorage system

was provided. The approximate cost of providing new post-tensioned rock anchors from 55 to 85 feet long with minimum of 20 feet embedment will range between \$580,000 to \$665,000, depending on the system selected. Additional investigation regarding a relaxation of the stability criteria for flood loading on existing structures is recommended in order to determine the necessity of a new anchorage.

The analysis of the fourth monolith from the east end was done at an assumed failure plane through rock, 10 feet below the concrete base. With the limited length of the rock beam because of daylighting at the downstream side, the minimum factor of safety against sliding is 1.47, approximately equal to the required 1.50. Maximum bearing pressure of 2.1T/S.F. is well below the allowable value at the site. The same monolith was analyzed at the interface of concrete base and the rock. Flood discharge loading will increase the foundation bearing pressure to a maximum of 5.4T/S.F., and the resultant will be outside of the middle third. Same anchorage system should be used on this monolith as selected for other monoliths.

TABLE 1

SPILLWAY

Monolith and Section	Loading Case	Location of Resultant		Percent Base-In Bearing	Resistance to Sliding Factor of Safety (1)	Bearing Pressures on Rock	
		In Middle Third	In Base			Maximum Tons/S.F.	Minimum
Central B/24	II	Yes	-	-	6.2	3.6	0.49
	IV	No*	Yes	78	4.2	4.7	-
	VI	Yes	-	-	4.8	4.2	-
West End A/24	II	Yes	-	-	63	0.5	0.33
	IV	Yes	Yes	-	16.4	0.5	-
	VI	Yes	-	-	36	0.5	0.38
East End E/26	II	Yes	-	-	17.3	2.1	0.53
	IV	No*	Yes	38	7.8	5.8	-
	VI	No	Yes	98	11.0	2.7	-
East End Fourth Monolith at Concrete Base	IV-2	No*	Yes	51	5.7	5.4	-
At 10 Feet Below Concrete Base in Rock Elevation 549	IV-2	Yes	-	-	1.47	2.1	1.24

*New anchorage system recommended.

(1) With allowable bond shear 75 psi.

II - Section 4 - Spillway Retaining Walls.

Near the dam, there are two retaining walls; one separates the earth-fill embankment from the spillway weir, and the other protects the downstream toe of the dam at the river channel from erosion at the outlet. Both walls are concrete gravity sections. The latter will be discussed in the next section, Concrete Toe Wall.

The retaining wall starts at one pier of the service bridge, includes the bridge abutment, connects with the east end of the spillway wall, and extends downstream about 150 feet from the spillway. The maximum height of this wall is about 55 feet, with a corresponding width of 40 feet, and the minimum height is 10 feet at the south end. The layout of this wall has two turns which add to the stability. This feature was not reflected in the design or in the stability analysis. The full length of the wall is founded on rock with embedment 2 to 3 feet deep.

The retaining wall was analyzed in accordance with EM 1110-2-2502 for "at rest" and "active" earth pressures, with no fill or water in front of the wall, with the following exceptions:

- (a) Upstream wall, during flood, with water on all sides of the wall.
- (b) For earthquake loads, passive resistance of rock embedment was used in computing sliding factor of safety.

Uplift pressures assumed are 100 percent of hydrostatic head at the heel and zero at the toe.

Loading cases considered were:

- Case I - Normal water level (maximum Elevation 610).
- Case IA - Normal water level plus earthquake.
- Case II - Floodwater level, Elevation 629.3.
- Case III - Water level on both sides up to Elevation 610.
- Case IIIA - Water level on both sides plus earthquake.

The latter two cases, III and IIIA, are applicable to walls on the upstream side of the spillway.

The tabulated critical values of factors of safety and bearing pressures for each wall section analyzed are shown in Table 2. With earthquake forces, the vertical resultant may be located outside of the middle third of the base. For such cases, the percentages of the width of base which will be in bearing are calculated. Neither of these pressures is excessive; therefore, all wall sections are acceptable as stable under all loading cases considered.

TABLE 2
SPILLWAY RETAINING WALLS

<u>Wall Section</u>	<u>Loading Case</u>	<u>Location of Resultant</u>		<u>Percent Base In Bearing</u>	<u>Resistance to Sliding Factor of Safety (1)</u>	<u>Bearing Pressures on Rock</u>	
		<u>In Middle Third</u>	<u>In Base</u>			<u>Maximum</u>	<u>Minimum</u>
D-25 (60 Feet High)	I	Yes	-	-	7.0	5.1	0.35
	II	Yes	-	-	14.3	3.0	0.78
	I-A	No	Yes	53	4.5	10.4	-
C-25 (60 Feet High)	I	Yes	-	-	9.3	4.6	0.37
	II	Yes	-	-	18.1	2.6	1.68
	III	Yes	-	-	14.3	3.2	0.30
	I-A	No	Yes	61	6.3	7.9	-
	III-A	No	Yes	60	8.1	5.7	-
F-25 High (45 Feet High)	I	Yes	-	-	7.9	3.6	0.42
	I-A	No	Yes	63	5.5	6.4	-
F-25 Low (31 Feet High)	I	Yes	-	-	9.8	2.6	0.21
	I-A	No	Yes	58	6.9	4.8	-

(1) With allowable bond shear 75 psi.

II - Section 5 - Concrete Toe Wall.

This retaining wall of concrete gravity section protects the downstream toe of the dam at the river crossing from erosion by the outlet flow. It was designed for hydrostatic head and lateral rock pressure. Having a total length of 232 feet, this wall varies in height from a maximum of 76 feet to a minimum of 5 feet. The wall consists of five different monoliths separated by expansion joints. The top elevation starts at Elevation 547.5 feet at the west end and slopes down to Elevation 500.6 feet at the other end. The design drawings show that the base of the toe wall is built on sound rock excavated several feet below the original rock line. In plan, this wall follows a circle with a radius of 156 feet. The arching of the structure in plan adds to its stability.

The analysis of stability was done for three different monoliths without relying upon the beneficial arching. The sections were analyzed as gravity walls for the following loading cases:

- Case I-1 - Full pool, water at the rear of toe wall at Elevation 503 feet (same as in the original design calculations, p. 130 revised).
- Case I-2 - Maximum flood, water at both sides of toe wall at Elevation 507 feet.
- Case II-1a - Loading consists of Case I-1, as outlined above, plus earthquake forces.

According to EM 1110-2-2502, Sec. 4.e., vertical resultant location outside the middle third is acceptable with lateral loading calculated "at rest." Accordingly, the use of middle third criteria with gravity walls on rock for "active" pressure produces an adequate factor of safety for "at rest" pressure. Therefore, this stability analysis was done using "active" pressure produced by the rock backfill ($\phi = 45^\circ$, $K_a = 0.19$). To allow for the effect of the backfill sloping upward, the horizontal force was applied at 0.45 times the height. The acceptable location of the resultant is within the middle third except with earthquake forces.

The tabulated critical values of factors of safety and bearing pressures for each monolith analyzed are shown in Table 3. None of these pressures are excessive and factors of safety calculated are better than the minimum required. Therefore, all wall sections can be considered to be stable under any loading condition.

TABLE 3
CONCRETE TOE WALL

<u>Wall Section</u>	<u>Loading Case</u>	<u>Location of Resultant</u>		<u>Percent Base In Bearing</u>	<u>Resistance to Sliding Factor of Safety (1)</u>	<u>Bearing Pressures on Rock</u>	
		<u>In Middle Third</u>	<u>In Base</u>			<u>Maximum</u>	<u>Minimum</u>
						<u>Tons/S.F.</u>	
Top Elevation 539 (76 Feet High)	I-1	Yes	-	-	6.7	7.2	0.45
	I-2	Yes	-	-	10.1	4.9	1.85
	II-1a	No	Yes	67	4.3	11.5	-
Top Elevation 528 (65 Feet High)	I-1	Yes	-	-	6.7	5.4	1.25
	I-2	Yes	-	-	10.4	3.6	1.90
	II-1a	No	Yes	78	4.6	8.6	-
Top Elevation 512 (28 Feet High)	I-1	Yes	-	-	16.0	2.9	0.19
	I-2	Yes	-	-	30.9	1.7	0.70
	II-1a	No	Yes	70	10.8	4.4	-

(1) With allowable bond shear 75 psi.

CONCLUSIONS

All of the Knightville Dam concrete structures analyzed for stability satisfy the prescribed requirements, except the spillway monoliths at maximum flood discharge condition. In those loading cases, the vertical resultant is located outside of the middle third of the base. The new stability requirements include 100 percent uplift at the base. If the stability criteria for existing structures at maximum flood loading cannot be relaxed to allow the resultant to fall outside of the kern but safely within the base, expensive remedial measures are necessary for the spillway. The recommended system of new drilled-in and grouted post-tensioned anchors is estimated to cost about \$600,000. All structures were analyzed for Seismic Risk Zone 2; but because the dam is located on the border line of Zone 1, a reduced acceleration factor could be justified.

MEMORANDUM

Site Visit to Knightville Dam on Westfield River
Huntington, Massachusetts
December 28, 1973

The writer and Mr. Sanat Patwari arrived at the site at 10 a.m. and were shown around by Mr. Louis Laford and his assistant. Visual inspection included the following structures:

1. The Dam. Walked along the roadway. Pavement did not show any holes, settlement, or cracks. The riprap on both sides looks like new. There was little water in the reservoir.
2. Intake Tower. All visible concrete surfaces appear to be in sound condition. We went by stairs down to the basement floor, Elevation 610, but not below. The gates were open; one by two feet, the other two by six inches.
3. Bridge Piers. No water on the riprap slope, both piers (and the abutment) visible all the way down. Concrete is in good condition.
4. Spillway Wall. The concrete at top of weir spalling and cracked. On the downstream side, several diagonal cracks and leaking construction joints visible. No misalignment. No cracks or defects at either abutment.
5. Retaining Wall at Spillway. Several construction joints (expansion joints revealed some deterioration of concrete) spalled away edges at top and at west sides.
6. Concrete Toe Wall. This was seen from the downstream side. No visible cracks.

Maximum water in the reservoir during December was on December 24, Elevation 83.3 feet. After having dropped to Elevation 70.0, it rose to 77.0 and now passes the tunnel at the rate of 3500 cubic feet per second. These elevations related to zero at outlet sill which is at Elevation 480 Mean Sea Level.

We did not notice any variances to conditions indicated on drawings and descriptions furnished to us that would affect the stability analysis of structures.

Eight photographs were taken. The temperature was about 32 degrees, mild, and sunny.

Jurgis Gimbutas

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